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THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

SEPTEMBER, 1959.

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HELIOTHIS AS A PEST OF COTTON IN CENTRAL QUEENSLAND

E.M.N.

By T. PASSLOW, M.Agr.Sc., Entomologist, Science Branch, Division of Plant Industry.

SUMMARY.

Over the 10-year period 1948–1957, 13 trials with modern insecticides against Heliothis armigera **(Hubn.) were conducted on both irrigated and rain-grown cotton in Central Queensland. Results from four of these trials show total yield increases after DDT applications which were successful in killing** Heliothis armigera; **the increase was economically significant in one instance only.**

During the 1955-56 season investigations were expanded to cover plant reaction to pest kills. Although goods kills of Heliothis and most other insects were obtained there was an increase in yields in the first pick but no differences among total yields. The killing of Heliothis caused the plants to hold larger percentages of early squares and bolls; later, however, fall from sprayed plants was sudden while that from unsprayed plants was gradual. Consequent replacement of squares and bolls was responsible for the levelling of total yields.

I. INTRODUCTION.

Heliothis armigera (Hubn.) has been considered a major pest of cotton in Central Queensland since the inception of the cotton-growing industry there.

One of the earliest recommendations on control in Queensland was that of Boyd (1908), who advocated growing maize or cowpeas as a trap crop in association with cotton. Ballard (1927) advised trap crops of maize and stated that calcium arsenate dust would stop an attack if two applications, a fortnight apart, were made when the crop was squaring. Currie (1928) advocated cultural measures, including planting as early as possible, as methods of escaping damage. Atherton (1932) stated that although Heliothis had been considered the most serious pest of cotton in the Callide Valley for some years it caused very little loss in 1931-32. He later reported (Atherton 1933) that bait trapping of Heliothis moths with several materials was of no value in controlling the insect in cotton. In 1935, Veitch considered that Heliothis in cotton could be neither successfully nor economically controlled with insecticides,

and recorded then (Veitch 1935) and again in 1938 (Veitch 1938) that maize trap crops were an advantage only if carefully handled. Sloan (1938) stated that maize trap crops had not been generally successful although the system had some advantages; in 1945 the same author (Sloan 1945) considered that migrating Heliothis larvae could be controlled either by baiting with Paris green or by spraying with lead arsenate. In 1951 (Officers of the Department of Agriculture and Stock 1951), the official recommendation was dusting or spraying with arsenate of lead when egg numbers on terminals rose above 7 per 25 terminals, in addition to cultural control. Passlow (1958) stated that in recent years many growers had used programme spraying, applying DDT at 0·2 per cent. in 25–50 gal. water per acre two weeks after germination and at the first major burst of squaring, with a third application three weeks later; some growers used DDT when egg numbers exceeded 15 per 100 terminals.

Field trials concerned with insecticide treatments were conducted annually from 1948 to 1957. All, except one during 1955-56 and one during 1956-57 in the Rockhampton district, were carried out on the Biloela Regional Experiment Station. The trials, using the variety Miller 41S, were designed to give insecticide (principally DDT) cover during major square and early boll development and the period of maximum Heliothis activity, and to ascertain the economic value of this protection.

II. MATERIALS.

The following insecticides were used:—

Aldrin.—An emulsifiable preparation containing 40 per cent. w/v active ingredient.

BHC.—A miscible oil preparation containing 6·5 per cent. w/v active ingredient.

DDT.—An emulsion concentrate containing 25 per cent. w/v *p.p'* isomer.

A dispersible china clay powder containing 50 per cent. *p.p'* isomer.

A kaolin dust containing 2·0 per cent. *p.p'* isomer.

Dieldrin.—An emulsifiable preparation containing 15 per cent. w/v active ingredient.

Endrin.—An emulsifiable preparation containing 20 per cent. w/v active ingredient.

Guthion.—An emulsifiable preparation containing 18 per cent. w/v active ingredient.

*Parathion E*605.—An emulsifiable preparation containing 25 per cent. w/v active ingredient.

III. METHODS.

Plot size was never less than 6 rows of cotton (3 ft. 6 in. inter-row spacing) each 1 chain long.

Heliothis egg counts were made each season. Prior to the 1955-56 season they were made on 100 terminals attractive to ovipositing moths selected at random on traverses of the trial area, and in later trials on terminals of 30 plants per plot selected at random in six groups of five. A terminal was taken as that part of the plant from the growing point to the fifth leaf from the top.

Insecticides were applied either by knapsack sprays and dusters or by mechanical boom sprays and dusters.

Observations on attacks by insects other than Heliothis were made.

Of the 13 trials, six were irrigated, and all were harvested by hand in one, two or three picks. Plot yields have been converted to the economic unit of pounds of seed cotton per acre.

During the 1955-56 season and at Rockhampton in 1956-57 some attention was given to plant behaviour in relation to pest control; fruit production assessments and insect damage counts were made. At Biloela (1955-56) four plants, at Rockhampton (1955-56) two groups of three plants, and at Rockhampton (1956-57) five plants in observation rows near the datum or yield rows in each plot, were selected and removed each week from the commencement of squaring until harvest. All squares and bolls were counted and the numbers damaged by insects recorded. Also, in 1955-56 all fruits fallen from these plants during the preceding week were collected and counted and the numbers damaged by insects were recorded. In 1956-57 all fruits fallen in two inter-row spaces each 20 ft. long were collected each week and treated as above.

Trial layout, details of treatments with insecticide dosage expressed as percentage of active ingredient and gallons of spray or pounds of dust per acre, and other relevant information, are given with the results of each trial.

IV. RESULTS.

(1) Trial 1. 1948-49. 2 x 10 Paired Plots. Irrigated.

The crop was planted on Oct. 26 and sprays were applied on Nov. 5 (seedling spray), Nov. 26, Dec. 16 and Jan. 24 at approximately 20, 35, 35 and 35 gal. per acre respectively. Light Heliothis infestations were present at spraying times and other pests were in negligible populations throughout the season. Harvesting was on Mar. 25–31 and July 2–7. The results are given in Table 1.

Table 1.

TRIAL 1. YIELDS.

Treatment.	1st Pick. (Lb./ac.).	2nd Pick. (Lb./ac.).	Total. (Lb./ac.).
DDT emulsion 0·4%	830	377	1,207
Check	687	435	1,122

Despite the small numbers of pests, DDT sprays increased first-pick yield (by 20·8 per cent.), but total yield was not increased.

(2) Trial 2. 1949-50. 4 x 5 Randomised Block. Irrigated.

The crop was planted on Oct. 18 and spray applications were made on Dec. 14 and Jan. 9 at 36 and 48 gal. per acre respectively. Maximum egg counts, on Dec. 14, Dec. 20, Jan. 3 and Jan. 12, were 16, 9, 6 and 7 per 100 terminals. Yields were obtained in three picks, on Mar. 20–23, May 11–15 and Aug. 2, and are given in Table 2.

Table 2.

TRIAL 2. YIELDS.

Treatment.	1st Pick. (Lb./ac.).	2nd Pick. (Lb./ac.).	3rd Pick. (Lb./ac.).	Total. (Lb./ac.).
DDT emulsion 0·4%	1,094	221	399	1,714
Parathion 0·015%	954	220	473	1,647
DDT emulsion 0·2% plus Parathion 0·0075%	1,048	230	320	1,598
Check	648	238	587	1,473
Necessary differences for significance .. 5%	143	49	119	125
Necessary differences for significance .. 1%	193	66	161	168

Although the incidence of pests was low, sprays gave significant increases in the first pick and in the total yields. DDT increased yields by 68·8 per cent. on the first pick and by 16·4 per cent. on the total yield.

(3) Trial 3. 1950-51. 4 x 10 Randomised Block. Irrigated.

The crop was planted on Oct. 13. Heliothis egg counts were low, maximum numbers being 9 per 100 terminals prior to the first spray and 17 per 100 terminals on Feb. 14. Treatments were the same as in Trial 2 and were applied on Dec. 19, Jan. 1 and Feb. 15 at 27, 45 and 40 gal. per acre respectively. Harvesting was on Mar. 19-28 and May 29-June 4. No significant yield differences were obtained. Mean yield was 1,240 lb. per acre.

(4) Trial 4. 1950-51. 2 x 12 Paired Plots. Not Irrigated.

The crop was planted on Oct. 13. Peak Heliothis egg counts of 6 and 28 per 100 terminals were recorded on Dec. 19 and Feb. 21. A moderate infestation of jassids (*Austroasca terrae-reginae* (Paoli) and *A. viridigrisea* (Paoli)) occurred prior to the second application. DDT as a 0·4 per cent. dispersible powder was applied on Dec. 19 and Jan. 30 at 20 and 40 gal. per acre and as a 2·0 per cent. dust on Feb. 16 at 24 lb. per acre.

Harvesting was on Mar. 30 and June 5–22. Yields are given in Table 3.

Table 3.

TRIAL 4. YIELDS.

Treatment.	1st Pick. (Lb./ac.).	2nd Pick. (Lb./ac.).	Total. (Lb./ac.).
DDT	602	628	1,230
Check	531	575	1,106

DDT significantly increased yields—by 13·4 per cent. on the first pick and by 11·2 per cent. on the total.

(5) Trial 5. 1951-52. 5 x 5 Randomised Block. Irrigated.

The crop was planted on Oct. 17. Peak Heliothis egg counts were on Dec. 7, 14 and 21 and Feb. 8 and 10, when 100, 41, 83, 8 and 10 eggs per 100 terminals respectively were recorded. Treatments were applied on Nov. 27, Dec. 12 and 22 and Feb. 5 at 18, 18, 30 and 40 gal. per acre respectively. Harvesting was on Apr. 8–May 5 and July 9. Yields are given in Table 4.

Table 4.

TRIAL 5. YIELDS.

Treatment.		1st Pick. (Lb./ac.).	2nd Pick. (Lb./ac.).	Total. (Lb./ac.).
DDT emulsion 0·4%		1,459	89	1,548
BHC 0·035%		1,257	142	1,399
Parathion 0·015%		1,251	136	1,387
Dieldrin 0·05%		1,226	153	1,379
Check		1,256	131	1,387
Necessary differences for significance	5%	147	40	120
	1%	202	55	166

DDT significantly increased yields—by 16·2 per cent. on the first pick and by 11·6 per cent. on the total yield. Dieldrin was used at a comparatively low application rate.

(6) Trial 6. 1952-53. 5 x 4 Randomised Block. Not Irrigated.

This crop was planted on Oct. 11. Peak Heliothis egg counts of 70, 12 and 17 per 100 terminals were recorded on Nov. 22 and Dec. 15 and 30. DDT was applied on Dec. 4 and 19 and Jan. 5 and 20, at 20 and 40 gal. per acre respectively. Harvesting was on Mar. 25–Apr. 7 and June 1–5. Yields are given in Table 5.

Table 5.

TRIAL 6. YIELDS.

Treatment.	1st Pick. (Lb./ac.).	2nd Pick. (Lb./ac.).	Total. (Lb./ac.).
DDT emulsion 0·13%	753	683	1,436
DDT emulsion 0·27%	851	663	1,614
DDT emulsion 0·40%	917	461	1,378
DDT emulsion 0·53%	878	443	1,321
Check	563	565	1,128

Yield increases to 63·0 per cent. occurred at the first pick but there were no differences among total yields. The non-uniformity of second-pick yields was related to more favourable soil moisture in some plots for second-pick growth.

(7) Trial 7. 1952-53. 5 x 4 Randomised Block. Irrigated.

The crop was planted on Oct. 15. Peak Heliothis egg counts of 76, 114 and 63 per 100 terminals were recorded on Dec. 4, 14 and 30. The same treatments as in Trial 6 were applied on Dec. 5 and 19 and Jan. 5 at 25, 40 and 40 gal. per acre. Harvesting was on May 1 and June 10 and no significant differences were obtained. The mean yield was 1,075 lb. per acre.

(8) Trial 8. 1953-54. 5 x 5 Latin Square. Irrigated.

The crop was planted on Oct. 31. Peak Heliothis egg counts of 36, 55, 18 and 70 per 100 terminals were recorded on Dec. 13 and 21 and Jan. 4 and 12. Treatments were DDT emulsion 0·1 per cent. and 0·05 per cent., DDT dust 2·0 per cent. and 1·0 per cent., and a check. Applications were made on Nov. 25, Dec. 15 and Jan. 6, the sprays being used at 25, 100 and 100 gal. per acre and the dusts at 25, 50 and 50 lb. per acre respectively. Harvesting was on Mar. 17–19, May 27–28 and July 16–19. No significant differences were obtained. The mean yield was 1,387 lb. per acre.

(9) Trial 9. 1954-55. 5 x 4 Randomised Block. Not Irrigated.

The crop was planted on Oct. 9. Peak Heliothis egg counts of 8, 61, 13 and 10 per 100 terminals were recorded on Dec. 22 and 30 and Jan. 7 and 13.

Two DDT emulsion treatments, applied through different types of boom sprays, and two DDT dust treatments applied by power duster, one with a trailing nylon sheet, were used. Applications were made on Dec. 2 and 24 at 1 lb. active ingredient in 15 gal. per acre and 50 lb. per acre respectively. Harvest was on Mar. 16–25 and July 13–18. No significant differences were obtained. The mean yield was 594 lb. per acre.

(10) Trial 10. 1955–56. 6 x 4 Randomised Block. Not Irrigated.

The crop was planted on Nov. 11. Heliothis egg counts were low except on Jan. 10 and 16 and Feb. 6, when 37·2, 2·5 and 6·1 per 100 terminals were recorded. Treatments were applied on Jan. 9 and 24, Feb. 7 and 22 and Apr. 7 at 60, 90, 90, 70 and 60 gal. per acre respectively. The last application was for attempted control of *Pectinophora scutigera* (Hold.), which was active during late March and April.

Each week the percentages of damaged and total number of squares and bolls held by the plants and the percentages damaged and numbers of fallen squares and bolls were recorded. These data are summarised in Table 6 for the whole production period (Jan. 16–May 15), and for fallen for the period of some insecticide cover (Jan. 16–Apr. 24). Prior to analyses of the percentages of squares and bolls damaged, the inverse sine transformation was used. Harvest was on Apr. 9–13 and May 31. Yields are given in Table 7.

Table 6.

Trial 10. Percentages Damaged and Total Numbers of Squares and Bolls.

Treatment.	Percentage of Damaged Squares and Bolls.					No. of Fallen Squares and Bolls.	
	In Weekly Examination on Plants.	In Fallen from Jan. 16 to Apr. 24.		In Fallen during Whole Period.		From Jan. 16 to Apr. 24.	During Whole Period.
		Trans. Mean.	Equiv. Mean %.	Trans. Mean.	Equiv. Mean %.		
DDT emulsion 0·1%	4·8	21·42	13·3	22·00	14·0	160·8	187·0
DDT emulsion 0·1% plus White oil 1 : 100 (wetting agent)	4·2	18·20	9·8	18·02	9·6	142·5	163·8
Endrin 0·05% ..	3·7	15·95	7·6	16·78	8·3	173·2	192·0
Dieldrin 0·1% ..	5·7	22·18	14·2	22·50	14·6	160·5	170·5
Aldrin 0·05% ..	8·6	24·32	17·0	24·75	17·5	160·0	171·0
Check	7·8	25·38	18·4	25·68	18·8	189·0	207·0
Necessary differences for significance 5%	..	4·05	..	3·26	..	56·0	52·0
Necessary differences for significance 1%	..	5·60	..	4·51	..	77·5	71·9

Table 7.

TRIAL 10. YIELDS.

Treatment.	1st Pick. (Lb./ac.).	2nd Pick. (Lb./ac.).	Total. (Lb./ac.).
DDT emulsion 0·1%	1,329	640	1,969
DDT emulsion 0·1% plus White oil 1 : 100 (wetting agent) ..	1,138	755	1,893
Endrin 0·05%	1,510	795	2,305
Dieldrin 0·1%	1,205	966	2,171
Aldrin 0·05	1,138	778	1,916
Check	1,009	952	1,961
Necessary differences for significance { 5%	202	..	229
Necessary differences for significance { 1%	281	..	322

Endrin and DDT gave significantly increased first-pick yields (DDT by 31·7 per cent), but only endrin increased total yields; this increase was due to control of the looper *Anomis flava* Fabr. and other leaf pests. Treatments had no significant effect on the numbers of squares and bolls lost by the plants, but in both the period of some insecticide cover and the whole examination period significantly fewer fallen squares and bolls were damaged by insects.

(11) Trial 11. 1955–56. 6 x 4 Randomised Block. Not Irrigated. Rockhampton.

The crop was planted on Nov. 4. Helothis egg counts were low, two minor peaks of 9·7 and 12·6 per 100 terminals occurring on Dec. 12 and Jan. 3 respectively. Treatments were applied on Jan. 11 and 25 and Feb. 15 and 29 at 50, 63, 63, and 84 gal. per acre respectively. As in Trial 10, each week the percentages of damaged and total numbers of squares and bolls held by the plants and the percentages damaged and numbers of fallen squares and bolls were recorded. These data are summarised in Table 8 for the whole production period (Jan. 19–June 13), and for fallen for the period of some insecticide cover (Jan. 19–Mar. 7). Prior to analyses of the percentages of squares and bolls damaged, the inverse sine transformation was used. Harvest was on Apr. 23–May 15 and June 18–21. Yields are given in Table 9.

The significant yield increases obtained in endrin and to a lesser extent in DDT plots were due to control of *Anomis flava*, which caused extensive leaf damage in check areas. Treatments had no significant effect on the numbers of fruits lost by the plants but significantly fewer fallen fruits were damaged by insects during the period of insecticide cover in DDT and endrin plots.

(12) Trial 12. 1956–57. 4 x 6 Randomised Block. Not Irrigated.

The crop was planted on Nov. 9. Heliothis egg numbers did not exceed 2·2 per 100 terminals except on Jan. 9, when 15 per 100 were recorded.

Table 8.

TRIAL 11. PERCENTAGES DAMAGED AND TOTAL NUMBERS OF SQUARES AND BOLLS.

Treatment.	Percentage of Damaged Squares and Bolls.					No. of Fallen Squares and Bolls.	
	In Weekly Examination on Plants.	In Fallen from Jan. 19 to Mar. 7.		In Fallen during Whole Period.		From Jan. 19 to Mar. 7.	During Whole Period.
		Trans. Mean.	Equiv. Mean %.	Trans. Mean.	Equiv. Mean %.		
DDT emulsion 0·1%	4·9	32·0	28·0	28·2	22·4	109·0	91·0
DDT emulsion 0·1% plus White oil 1 : 100 (wetting agent)	4·9	29·4	24·1	28·0	22·0	96·0	89·5
Endrin 0·05% ..	4·8	30·2	25·3	24·6	17·4	90·0	77·8
Dieldrin 0·1% ..	5·6	40·6	42·4	31·0	26·4	79·2	85·2
Aldrin 0·05% ..	6·2	38·3	38·4	33·4	30·2	107·5	90·0
Check	5·9	42·4	45·5	32·8	29·4	80·8	83·2
Necessary differences for significance 5%	..	9·8	..	8·3	..	39·4	21·6
Necessary differences for significance 1%	..	13·5	..	11·4	..	54·4	29·9

Table 9.

TRIAL 11. YIELDS.

Treatment.	1st Pick. (Lb./ac.).	2nd Pick. (Lb./ac.).	Total. (Lb./ac.).
DDT emulsion 0·1%	536·8	230·3	767·1
DDT emulsion 0·1% plus White oil 1 : 100 (wetting agent) ..	431·9	286·6	718·5
Endrin 0·05%	573·7	269·7	843·4
Dieldrin 0·1%	391·6	220·3	611·9
Aldrin 0·05%	444·7	230·3	675·0
Check	261·8	272·5	534·3
Necessary differences for significance 5%	136·1	..	232·3
Necessary differences for significance 1%	187·9	..	321·5

Four applications of the treatments DDT emulsion 0·1 per cent., endrin 0·05 per cent. and guthion 0·1 per cent. were given at 30 gal. per acre on Jan. 9 and 23 and Feb. 6 and 20. Harvesting was on Apr. 12–14; no significant differences were obtained. The mean yield was 636 lb. per acre.

(13) Trial 13. 1956–57. 4 x 6 Randomised Block. Not Irrigated. Rockhampton.

The crop was planted on Nov. 16. Heliothis egg counts were low, maximum records being 7·8 and 16·1 per 100 terminals on Feb. 5 and 26 respectively. Treatments were applied on Jan. 30, Feb. 13 and 28 and Mar. 13 at 112, 118, 114, and 130 gal. per acre respectively.

Table 10.

TRIAL 13. PRODUCTION AND NUMBERS OF DAMAGED AND TOTAL FALLEN SQUARES AND BOLLS.

Treatment.	Square and Boll Production from Five Plants per Plot per Week.			Numbers of Damaged Fallen Squares and Bolls.			Total Numbers of Fallen Squares and Bolls.		
	Until Feb. 26.	Until 1st Pick.	Damaged until 1st Pick.	Until Feb. 26.		Until 2nd Pick.	Until Feb. 26.		Until 2nd Pick.
				Means.	Equiv. Mean Nos.	Mean Nos.	Means.	Equiv. Mean Nos.	Mean Nos.
DDT emulsion 0·1%	26·5	44·9	12·7	3·80	14·4	73·8	5·16	26·6	251·9
Endrin 0·05% ..	36·3	48·9	18·4	4·64	21·5	108·7	5·43	29·5	238·1
Guthion 0·1% ..	24·4	43·6	19·0	5·65	31·9	117·9	6·59	43·4	255·2
Check	35·2	64·8	25·5	7·69	59·1	145·9	8·25	68·1	339·2
Necessary differences for significance 5%	10·6	15·3	9·8	2·34	..	62·1	2·23	..	99·5
Necessary differences for significance 1%	14·7	21·2	13·5	3·23	..	85·9	3·08	..	137·5

As in 1955–56, each week the percentages damaged and total numbers of squares and bolls held by the plants and the numbers damaged and total numbers of fallen squares and bolls were recorded. The production of

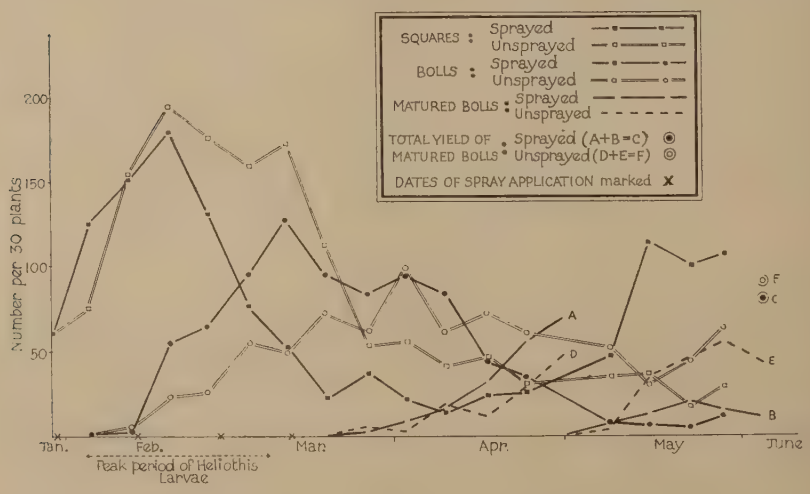

Fig. 1.

Plant Behaviour and Yields. Trial 13, 1956-57.

squares and bolls each week has been calculated and these and other data are summarised in Table 10, the square root transformation being used where necessary. Production figures and data of fallen squares and bolls are presented for the period Jan. 29 to Feb. 26, during which major square and boll loss occurred, and for the whole period Jan. 29 to May 28. The numbers of squares and bolls on the plants each week are given in Fig. 1. Harvest was on May 1–3 and June 4. The yields are given in Table 11.

Table 11.

TRIAL 13. YIELDS.

Treatment.	1st Pick. (Lb./ac.).	2nd Pick. (Lb./ac.).	Total. (Lb./ac.).
DDT emulsion 0·1%	392·7	41·6	434·3
Endrin 0·05	328·5	78·5	407·0
Guthion 0·1%	271·7	94·5	366·2
Check	224·0	192·7	416·7
Necessary differences for significance 5%	80·2	..	101·9
Necessary differences for significance 1%	111·0	..	140·9

This trial was conducted under very dry conditions. Although DDT treated plots gave significantly increased first-pick yields the high numbers of early squares were not produced as in other trials carried out under better field conditions.

V. DISCUSSION.

Early workers with cotton in Central Queensland assumed that Heliothis was a serious pest, and to assure production attempted to protect the crops during early squaring. Several cultural methods were suggested, and insect applications followed the American pattern (e.g. Gaines 1939), using Heliothis egg counts as a guide to spraying. Most of these investigations were limited to observations.

In this paper, trials with modern insecticides over a 10-year period are recorded. Of the 13 conducted in both irrigated and rain-grown crops, results from four show total yield increases after DDT applications: the increase was economically significant only in Trial 2. In this trial the use of parathion, which is not particularly efficacious in killing Heliothis, was also responsible for increased total yields. Furthermore, in trials where DDT and materials of only moderate value against Heliothis were used there were no significant differences among total yields. Until the 1955–56 season, entomological observations concerned with these trials were limited to Heliothis egg counts. In that season more detailed investigations, also covering plant behaviour, were commenced; and although good kills of Heliothis and most other insects were obtained, there was an increase in yields in the first pick

but no differences among total yields. The killing of Heliothis caused the plants to hold larger percentages of early squares and bolls; later, however, fall from sprayed plants was sudden while that from unsprayed plants was gradual. Consequent replacement of squares and bolls was responsible for the levelling of total yields (See Fig. 1 and Passlow 1958). Current entomological research on cotton pests is following the approach as used during the 1955–56 season. The main interest, however, is not in killing insects, for which purpose satisfactory methods are readily available, but rather in correlating these kills with yields from crops grown under differing agronomic conditions.

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EFFECT OF HIGH SOIL TEMPERATURES ON *RHIZOBIUM* SPP.

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SUMMARY.

Following field observations of poor nodulation of legumes sown on hot days, the possible effects of high soil temperatures on legume bacteria were studied.

Eighty-seven strains of legume bacteria on nutrient agar showed maximum temperatures for growth of 31-38.4 deg. C., 32-32.7 deg. C., 36.5-42.5 deg. C. and 30-42.0 deg C. for clover, pea, medic, and tropical legume strains of Rhizobium **respectively.**

Studies of the decline of viable population in sterile wallum-heath sand at 40 deg. C. indicated the rapid death of pea and clover strains; the death of tropical legume strains within 10 hours; and an initial drop of numbers of lucerne organisms followed by a lesser death rate.

Sowing inoculated seed into moist soil followed by holding at 40 deg. C. before planting showed that strain of legume bacterium, initial concentration of inoculum and time of subjection to high temperatures are significant factors operating in the survival of legume bacteria on the seed.

Methods of overcoming deleterious effects of high soil temperatures are discussed.

I. INTRODUCTION.

In field plots at Coolum in south-eastern Queensland in 1957 it was observed that only a small percentage of seedlings of various tropical legumes, red clover (*Trifolium pratense* L.) and white clover (*T. repens* L.) formed nodules when planted following midsummer to late-summer rains. Neither poor moisture nor nutrient deficiency could be invoked to explain the defective nodulation. Watering of a suspension of the same bacterial strain onto rows some weeks later resulted in good nodulation. This suggested that the environmental conditions at planting were deleterious to the legume bacteria.

High soil temperature appeared to be a factor to be considered and consequently a systematic study of the effect of high temperatures on the growth and survival of legume bacteria was commenced. Many of the early studies on the temperature requirements of legume bacteria were directed to finding the optimum temperature for development. The present study was designed to investigate the maximum temperature for growth and the harmful effect of high soil temperature on survival in the soil and on the seed.

II. MAXIMUM TEMPERATURE FOR GROWTH.

References to the maximum temperature tolerance of legume bacteria are somewhat variable. De Rossi (1907) found no growth of organisms from *Vicia faba* L. incubated at 37 deg. C. and frequently none at 35 deg. C. Müller and Stapp (1925) considered 32–33 deg. C. to be harmful to most rhizobia. Gangulee (1926), working with a lucerne organism, obtained a decreased population in soil within seven days with temperatures of 35 deg. C. and 50 deg. C. Studies by Allison and Minor (1940) indicated a maximum temperature for growth of five rhizobium strains, from the clover, pea and bean groups and the strain-specific *Dalea,* to be 31–37 deg. C., and for four lucerne rhizobia 39 deg. C. The experiment, however, was conducted over 48 hours only and a slow growth at the high temperatures could have been overlooked.

More recently Ishizawa (1953) made a survey of 94 rhizobium strains from various legumes. His data show maximum temperatures of growth for the various cross-inoculation groupings as follows: pea, clover and bean 35–37 deg. C., medic 40·5–42·5 deg. C., lupin 32–33 deg. C. and the tropical legume miscellany (including soybean) 32–42·5 deg. C. The work reported here has in some instances confirmed and in others modified these findings.

The primary investigation was the assessment of the maximum temperature for growth on agar slopes. Eighty-seven strains of legume bacteria drawn from four cross-inoculation groupings were used, with most strains being selected from the tropical legume miscellany.

Duplicate tubes of asparagus extract-mannitol-mineral salts agar (Allen 1951) were inoculated, and incubated for at least 14 days in a series of chambers of a multi-temperature incubator. Ten chambers of the incubator were employed, giving a range of temperatures between 22 deg. C. and 45 deg. C. Daily readings indicated a fluctuation of temperature of ±0·7 deg. C. Tubes showing no growth at the completion of the trial period were returned to a temperature suitable for growth. In no case was subsequent growth observed.

The results are summarised in Table 1, and detailed strain data are given in Appendix 1.

Table 1.

MAXIMUM TEMPERATURES FOR GROWTH ON AGAR SLOPES.

Cross-inoculation Group.	No. of Strains Tested.	Maximum Temperature for Growth. (°C.).		
		Lowest.	Highest.	Average.
Medic	8	36·5	42·5	41·0
Trifolium	9	31·0	38·4	33·2
Pea	2	32·0	32·7	32·3
Tropical Legume Miscellany	68	30·0	42·0	35·4

Marked differences between some groups and also within groups are obvious. While being in general agreement with the results of early workers, the maximum temperatures for growth of the pea and the clover groups (average 32·3 deg. C. and 33·2 deg. C., respectively) are lower than those found by Ishizawa (1953). The high maximum temperature for growth of medic organisms is marked. The tropical legume miscellany shows wide variation.

An examination of the data for the tropical legume miscellany with respect to botanical affinities and latitude of occurrence did not reveal any correlation.

III. EFFECT OF HIGH TEMPERATURE ON LONGEVITY AND NODULATION IN SOIL.

(1) Laboratory Trial 1.

Nine strains of legume bacteria of various types were inoculated into sterile wallum-heath sand and incubated at 28 deg. C. and 40 deg. C. This was done by adding 5 ml. of a suspension from a 10-days-old culture of the organism to a series of bottles each containing 20 g. of sterile sand. Counts of viable cells were made at 2-hourly intervals for 12 hours and one at 24 hours, using the Miles-Misra drop plate counting technique. The viable organisms in duplicate bottles for each temperature were counted at each sampling time.

The results presented in Table 2 are the average of the two determinations, counting from 8 drops per dilution in each determination, and are expressed as number of viable organisms per gram of sand.

Figs. 1, 2 and 3 show the death curves for organisms from medic, from clover and pea, and from tropical legume groupings respectively.

The results show the marked killing effect of incubation at 40 deg. C., particularly on pea and clover organisms. The large initial loss of viability of medic organisms followed by a levelling of the curve need not necessarily be interpreted as a selection within a population inherently heterogeneous with respect to high temperature resistance.

The normally recommended level of inoculum for legume seed is 1,000 organisms per seed. The survival time for these would be low in such soils as the test one at Coolum, where temperatures of up to 47·5 deg. C. are recorded at planting depth and where 40 deg. C. is exceeded for up to six hours per day.

Table 2.

EFFECT OF HIGH TEMPERATURE ON LONGEVITY OF LEGUME BACTERIA IN WALLUM-HEATH SAND.

Host of Isolation and Strain.	Maximum Temperature for Growth (°C.).	Temp. of Incubation (°C.).	Incubation Time (Hours).							
			0.	2.	4.	6.	8.	10.	12.	24.
Medicago sativa L. (QA383)	40	28	$2{\cdot}91 \times 10^6$†	$2{\cdot}93 \times 10^6$	$2{\cdot}79 \times 10^6$	$2{\cdot}35 \times 10^6$	$2{\cdot}65 \times 10^6$	$1{\cdot}95 \times 10^6$	—	$4{\cdot}74 \times 10^5$
		40	$2{\cdot}91 \times 10^6$*	$2{\cdot}70 \times 10^6$	$2{\cdot}14 \times 10^6$	$9{\cdot}16 \times 10^5$	$1{\cdot}79 \times 10^6$	$1{\cdot}30 \times 10^5$	$1{\cdot}24 \times 10^5$	$6{\cdot}06 \times 10^3$
M. sativa. (QA679)	36·5	28	$2{\cdot}86 \times 10^6$	$2{\cdot}26 \times 10^6$	$2{\cdot}25 \times 10^6$	$1{\cdot}98 \times 10^6$	$2{\cdot}40 \times 10^6$	$2{\cdot}13 \times 10^6$	$2{\cdot}21 \times 10^6$	$6{\cdot}74 \times 10^5$
		40	$2{\cdot}86 \times 10^6$	$2{\cdot}81 \times 10^6$	$1{\cdot}19 \times 10^6$	$2{\cdot}16 \times 10^5$	$1{\cdot}15 \times 10^4$	$3{\cdot}34 \times 10^4$	$7{\cdot}33 \times 10^2$	$7{\cdot}74 \times 10^2$
Trifolium pratense L.(QA382)	32·7	28	$1{\cdot}45 \times 10^6$	$9{\cdot}11 \times 10^5$	$1{\cdot}16 \times 10^6$	$1{\cdot}34 \times 10^6$	$7{\cdot}72 \times 10^5$	$1{\cdot}10 \times 10^6$	$5{\cdot}06 \times 10^5$	$5{\cdot}90 \times 10^5$
		40	$1{\cdot}45 \times 10^6$	$1{\cdot}85 \times 10^5$	$7{\cdot}03 \times 10^4$	$1{\cdot}87 \times 10^3$	0	0	0	0
Trifolium repens L. (QA859)	32	28	$2{\cdot}17 \times 10^5$	$2{\cdot}08 \times 10^5$	$2{\cdot}12 \times 10^5$	$2{\cdot}45 \times 10^5$	$3{\cdot}06 \times 10^5$	$1{\cdot}61 \times 10^5$	$2{\cdot}00 \times 10^5$	$1{\cdot}78 \times 10^5$
		40	$2{\cdot}17 \times 10^5$	$7{\cdot}99 \times 10^4$	$1{\cdot}09 \times 10^4$	$5{\cdot}63 \times 10^2$	$1{\cdot}78 \times 10^2$	0	0	0
Pisum sativum L. (QA794) ..	32	28	$1{\cdot}77 \times 10^5$	$1{\cdot}47 \times 10^5$	$1{\cdot}65 \times 10^5$	$2{\cdot}11 \times 10^5$	$1{\cdot}14 \times 10^5$	$1{\cdot}20 \times 10^5$*	$1{\cdot}41 \times 10^5$	$1{\cdot}05 \times 10^5$
		40	$1{\cdot}77 \times 10^5$	$1{\cdot}59 \times 10^5$	$1{\cdot}07 \times 10^5$	$1{\cdot}12 \times 10^3$	0	0	0	0
Pultenaea villosa Willd. (QA323)	35·6	28	$1{\cdot}30 \times 10^6$	$9{\cdot}90 \times 10^5$	$6{\cdot}37 \times 10^5$	$5{\cdot}36 \times 10^5$	—	$2{\cdot}03 \times 10^6$	$8{\cdot}91 \times 10^5$	$4{\cdot}25 \times 10^5$
		40	$1{\cdot}30 \times 10^6$	$1{\cdot}03 \times 10^6$	$6{\cdot}04 \times 10^5$	—	$1{\cdot}34 \times 10^5$	0	0	0
Centrosema pubescens Benth. (QA549)	38·5	28	$4{\cdot}03 \times 10^6$	$3{\cdot}41 \times 10^6$	$3{\cdot}43 \times 10^6$	$3{\cdot}66 \times 10^6$	$3{\cdot}34 \times 10^6$	$3{\cdot}16 \times 10^6$	$2{\cdot}69 \times 10^6$	$1{\cdot}44 \times 10^6$
		40	$4{\cdot}03 \times 10^6$	$3{\cdot}88 \times 10^6$	$2{\cdot}58 \times 10^6$	$2{\cdot}44 \times 10^6$	$7{\cdot}80 \times 10^5$	$8{\cdot}32 \times 10^4$	$3{\cdot}84 \times 10^5$	$2{\cdot}65 \times 10^3$
C. pubescens. (QA837) ..	35·2	28	$4{\cdot}24 \times 10^6$	$4{\cdot}72 \times 10^6$	$4{\cdot}69 \times 10^6$	$4{\cdot}15 \times 10^6$	$4{\cdot}08 \times 10^6$	$4{\cdot}18 \times 10^6$	$2{\cdot}90 \times 10^6$	$3{\cdot}45 \times 10^6$
		40	$4{\cdot}24 \times 10^6$	$4{\cdot}34 \times 10^6$	$2{\cdot}70 \times 10^6$	$1{\cdot}84 \times 10^4$	$4{\cdot}25 \times 10^3$*	$1{\cdot}39 \times 10^4$*	0	0
C. pubescens. (QA851) ..	33	28	$3{\cdot}54 \times 10^6$	$3{\cdot}41 \times 10^6$	$3{\cdot}44 \times 10^6$	$3{\cdot}66 \times 10^6$	$3{\cdot}34 \times 10^6$	$3{\cdot}16 \times 10^6$	$2{\cdot}70 \times 10^6$	$1{\cdot}44 \times 10^6$
		40	$2{\cdot}54 \times 10^6$	$3{\cdot}23 \times 10^6$	$1{\cdot}80 \times 10^6$	$5{\cdot}08 \times 10^5$*	$5{\cdot}67 \times 10^3$	0	0	0

† Viable organisms per gram of sand.
* Results of 1 bottle only.

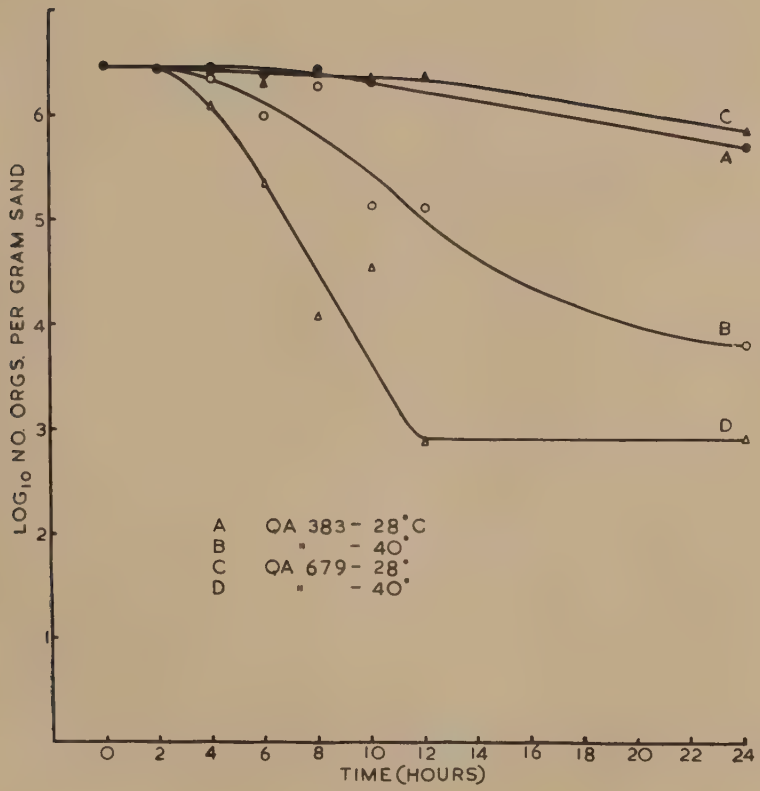


Fig. 1.

Death Curves for Medic Isolates.

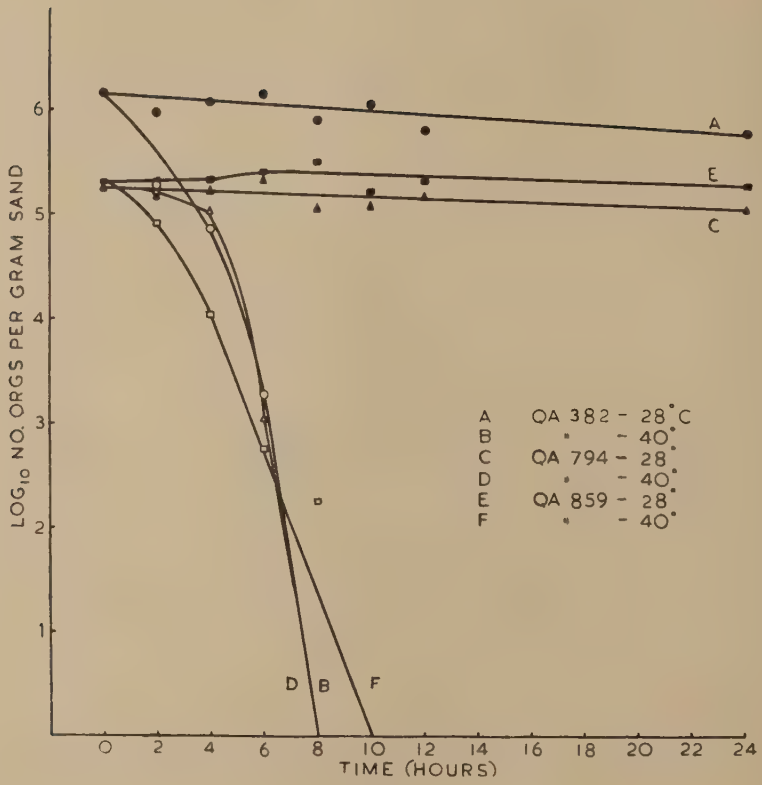


Fig. 2.

Death Curves for Clover and Pea Isolates.

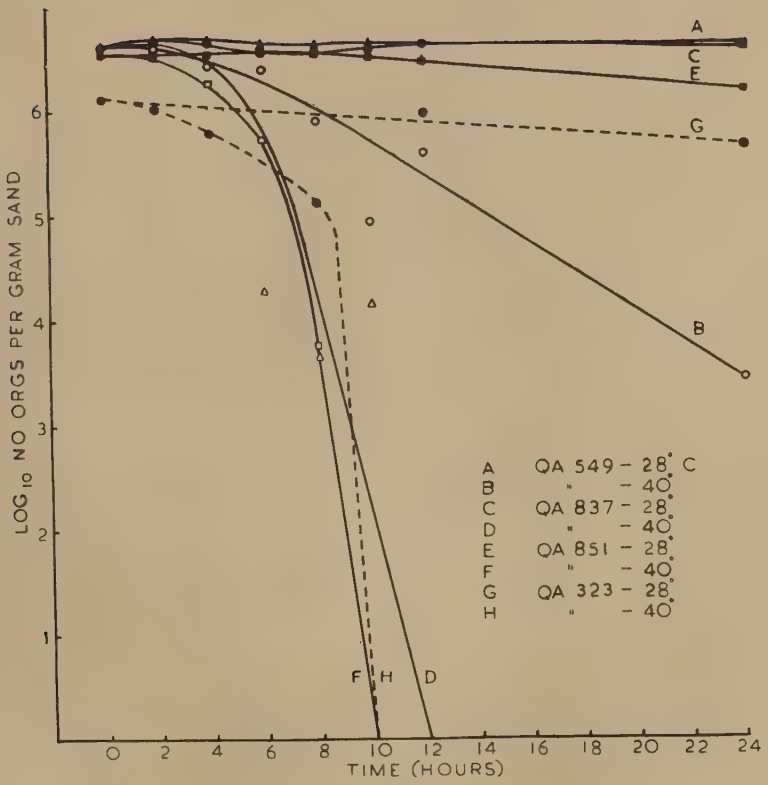


Fig 3.

Death Curves for Tropical Legume Isolates.

(2) Laboratory Trial 2.

Wallum-heath sand was inoculated as in Trial 1 with four strains only, but at two concentrations of bacteria, one being 100 times the other. The sand cultures were incubated at 40 deg. C., and counts made every two hours up to 12 hours. The results are shown in Table 3 and Figs. 4 and 5.

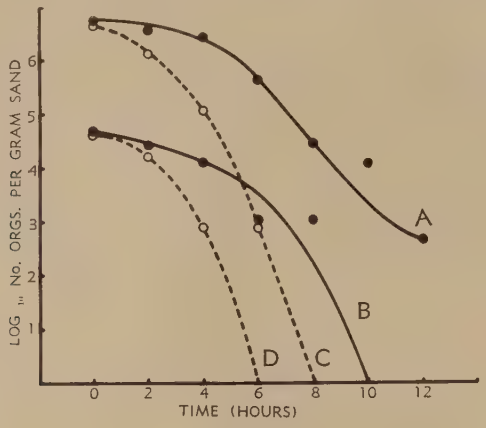


Fig. 4.

Death Curves for Two Concentrations of *Centrosema* Isolates.

A—QA549 at higher concentration.
B—QA549 at lower concentration.
C—QA851 at higher concentration.
D—QA851 at lower concentration.

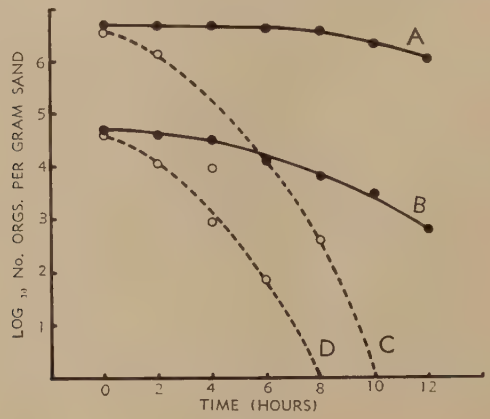


Fig. 5.

Death Curves for Two Concentrations of Medic and Clover Isolates.

A—QA383 at higher concentration.
B—QA383 at lower concentration.
C—QA859 at higher concentration.
D—QA859 at lower concentration.

Table 3.

EFFECT OF HIGH TEMPERATURE ON LEGUME BACTERIA APPLIED TO WALLUM-HEATH SAND AT TWO CONCENTRATIONS.

Host of Isolation and Strain.	Concentration.	Hours Incubated at 40°C.						
		0.	2.	4.	6.	8.	10.	12.
Medicago sativa (QA383)	100x	$5{\cdot}04 \times 10^6$*	$4{\cdot}80 \times 10^6$	$5{\cdot}01 \times 10^6$	$4{\cdot}11 \times 10^6$	$3{\cdot}92 \times 10^6$	$2{\cdot}05 \times 10^6$	$1{\cdot}12 \times 10^6$
	x	$4{\cdot}91 \times 10^4$	$4{\cdot}08 \times 10^4$	$3{\cdot}34 \times 10^4$	$1{\cdot}26 \times 10^4$	$6{\cdot}61 \times 10^3$	$3{\cdot}20 \times 10^3$	$6{\cdot}83 \times 10^2$
Trifolium repens (QA859)	100x	$3{\cdot}41 \times 10^6$	$1{\cdot}32 \times 10^6$	$9{\cdot}72 \times 10^6$	$1{\cdot}19 \times 10^4$	$4{\cdot}16 \times 10^2$	0	0
	x	$3{\cdot}99 \times 10^4$	$1{\cdot}24 \times 10^4$	$9{\cdot}50 \times 10^2$	$7{\cdot}92 \times 10$	0	0	0
Centrosema pubescens (QA549)	100x	$5{\cdot}77 \times 10^6$	$3{\cdot}75 \times 10^6$	$2{\cdot}75 \times 10^6$	$4{\cdot}32 \times 10^5$	$3{\cdot}06 \times 10^4$	$1{\cdot}29 \times 10^4$	$5{\cdot}02 \times 10^2$
	x	$5{\cdot}03 \times 10^4$	$2{\cdot}64 \times 10^4$	$1{\cdot}31 \times 10^4$	$1{\cdot}09 \times 10^3$	$1{\cdot}11 \times 10^3$	0	0
C. pubescens (QA851)	100x	$4{\cdot}47 \times 10^6$	$1{\cdot}38 \times 10^6$	$1{\cdot}21 \times 10^5$	$7{\cdot}20 \times 10^2$	0	0	0
	x	$4{\cdot}18 \times 10^4$	$1{\cdot}68 \times 10^4$	$7{\cdot}99 \times 10^2$	0	0	0	0

* Viable organisms per gram of sand.

These results show that when the initial concentration of the legume bacteria is higher, a longer exposure to high temperature is required for their serious depletion or complete kill. The strain differences found in Trial 1 also occurred in this trial.

(3) Glasshouse Trial.

Following the field observations and preliminary laboratory data on decline of the legume bacteria population in soil, a glasshouse trial was planted to test the effect on nodulation of strain of bacterium, level of inoculation and time of subjection of inoculated seed to the high temperature.

The test plant used was the tropical legume *Centrosema pubescens* Benth. Surface-sterilized seed was inoculated at each of two levels of inoculum (1×10^3 organisms per seed and 1×10^5 organisms per seed) with each of two strains previously found effective for this legume. These strains were QA549 and QA837, with maximum temperatures for growth of 38·5 deg. C. and 35·2 deg. C. respectively. The inoculated seed was sown in sterilized sand plus nutrients and incubated at 40 deg. C. for 0, 3, 6 and 9 hours before planting into aseptic testing units of a modified Leonard jar type. Thirty seeds per jar were sown to yield approximately 10–15 seedlings. Six randomised replications were employed. Records of the presence of nodules and counts of nodules were made after six weeks. These results are shown in Tables 4 and 5 respectively.

Table 4.

PERCENTAGE OF *Centrosema pubescens* PLANTS NODULATED IN GLASSHOUSE TRIAL.

Strain.	Concentration of Inoculum.	Hours Incubated at 40°C.			
		0.	3.	6.	9.
QA837 ..	Low ..	93·1	34·7	8·5	3·0
	High ..	90·9	45·0	14·5	36·6
QA549 ..	Low ..	91·3	82·5	24·2	28·6
	High ..	83·1	83·1	78·4	82·2

Within Low concentration 0>>3>>6, 9
Within High concentration 0>>3>>6 ; 0>>9, 6
Within Strain QA837 0>>3>>9, 6
Within Strain QA549 0>>9,6 ; 3>9 ; 3>>6

Before statistical analyses of the percentage of plants with nodules was proceeded with, the inverse sine transformation was used to equalise variances. Before analyses of numbers of nodules per plant, the log $(1 + x)$ transformation was used. Individual plot results and the summaries of statistical analyses are shown in Appendices 2 and 3 respectively.

Table 5.

AVERAGE NODULE NUMBERS PER PLANT IN GLASSHOUSE TRIAL.

Strain.	Concentration of Inoculum.	Hours Incubated at 40°C.			
		0.	3.	6.	9.
QA837 ..	Low ..	4·0	0·9	0·35	0·0
	High ..	3·0	1·3	0·8	1·5
QA549 ..	Low ..	5·5	3·0	0·5	1·3
	High ..	3·8	3·3	4·5	3·6

Within Low concentration 0>>3>>9, 6
Within High concentration 0>6 ; 0>>9
Within Strain QA837 0>>3>6, 9 ; 3>>9
Within Strain QA549 0, 3>>6 ; 0>>9

Despite variable individual plot values, interactions of strains and times and concentration and times are highly significant for the percentage of plants with nodules. For numbers of nodules per plant, interaction of concentrations and times is highly significant. Here variation between plots of the one treatment arose from some individual plants being heavily nodulated. This may be inherent in the plant (Bowen, unpublished data) or due to a high survival of organisms on particular seeds. The individual plot variations were not unexpected. It is thought likely that some spreading from plant to plant may have occurred. Ideally such experiments would be better conducted with single-plant pots.

Strain QA549, while not as susceptible to high temperature damage as QA837, is affected by a longer exposure. The difference between the strains is one of degree, not of type. It is considered that even with QA549 at the high inoculum rate considerable mortality occurred, but that populations were not reduced below those necessary for nodulation to take place. A longer high temperature exposure on the same day (or perhaps on succeeding days) may have killed these. Under ideal pot testing conditions, it is likely that almost complete kill of the organisms would have been necessary to prevent nodulation.

IV. FIELD TEMPERATURE STUDIES.

For the purposes of the present study information on soil temperatures attained in moist soil at a depth approximating planting (1–2 in.) was required. In the tropics, Ramdas and Dravid (1936) recorded temperatures of up to 64·6 deg. C. at the surface and 45·3 deg. C. at 5 cm. depth in a black soil.

Breakwell and Jenkins (1951) recorded soil temperatures of 112 deg. F. (44·4 deg. C.) 1 in. below ground level in clean-cultivated soil in the Richmond River area of New South Wales (latitude 29 deg. S.). Crofts (1957) recorded 1 in. temperatures of 100–124 deg. F. (37·8–51·1 deg. C.) in fallow in the same soils in the period November 1951 to February 1952. Temperatures recorded by the authors at Coolum, South Queensland (latitude 26·5 deg. S.) in the grey sandy coastal wallum-heath soils, on a typical summer day (February 1958), in moist bare soil showed that temperatures can reach 47·5 deg. C. at 1 in. and 42·5 deg. C. at 2 in. depths. At 1 in., temperatures of over 40 deg. C. were maintained for up to six hours. Results over two years (unpublished records of Chemical Laboratory, Queensland Department of Agriculture and Stock) indicate that from April to September inclusive, temperatures in moist soil in the same area at 1 in. do not rise over 90 deg. F. (32·2 deg. C.), while from November to February, temperatures of over 100 deg. F. (37·8 deg. C.) in moist soil at 1 in. are not unusual.

In order to test ways of overcoming high soil temperatures in the field, temperatures were recorded at Coolum at 1 in. and 2 in. depths with the following paired sites:

(1) Bare soil and an established pasture mixture of para grass (*Brachiaria mutica* Stapf).

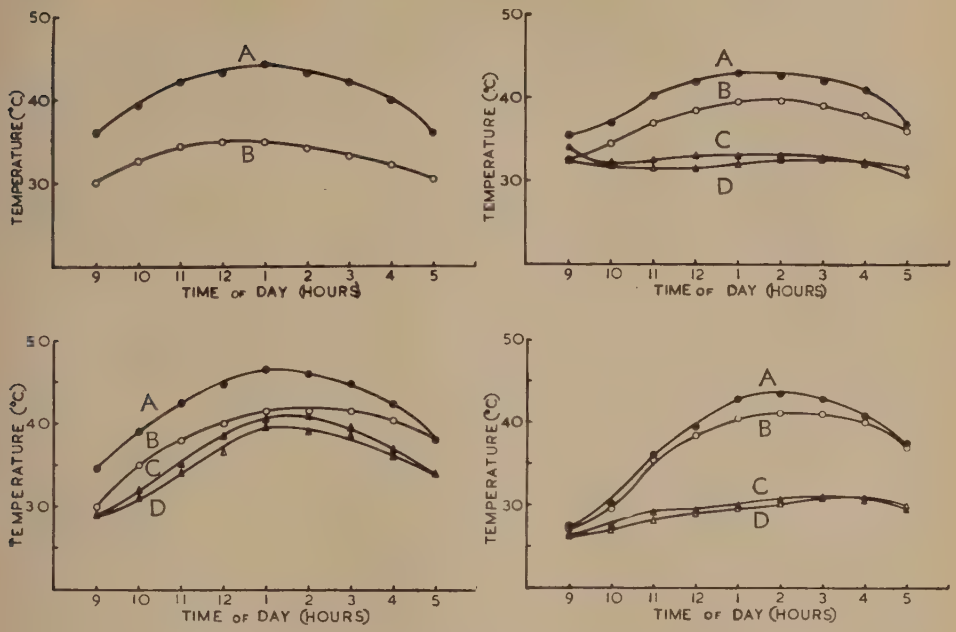
(2) Bare soil and native heath vegetation.

(3) Bare soil and a covering 3 in. plant trash layer.

(4) Bare soil on the western side of an established grass plot and bare soil in grass shade on the southern side of the plot.

The soil was moist and the day (Feb. 5, 1958) a typical cloudless summer day. In each pair the sites were no more than 3 ft. apart to reduce variation due to soil factors.

Figs. 6–9 show the type of results obtained on the respective sites. In all cases lower temperatures were recorded where shade was provided. Under trash, temperatures remained stationary during the day. The peaks in the 2 in. depth curves correspond in time to those at 1 in. While maximum temperatures were recorded at 1 p.m., temperatures under bare ground remain above the maximum for growth of many rhizobium strains for considerable periods.



Figs. 6–9.

Soil Temperatures Measured in the Field at 1 in. and 2 in. Depths at Paired Sites of Bare and Covered Ground.

Fig. 6.—A—Bare ground.
B—Para grass cover.

Fig. 7.—A—Bare soil at 1 in. depth.
B—As A at 2 in. depth.
C—Native heath cover at 1 in. depth.
D—As C at 2 in. depth.

Fig. 8.—A—Bare soil at 1 in. depth.
B—As A at 2 in. depth.
C—Plant trash cover at 1 in. depth.
D—As C at 2 in. depth.

Fig. 9.—A—Bare soil on western side of an established grass plot at 1 in. depth.
B—As A at 2 in. depth.
C—Bare soil in grass shade on southern side of the plot at 1 in. depth.
D—As C at 2 in. depth.

V. DISCUSSION.

The results support the thesis that high soil temperatures attained in summer in subtropical and tropical environments can be a factor hampering the establishment of sown pastures. The aspect studied here has been entirely one of the survival of the legume bacteria. Because of the sparsity of experimental equipment for controlling glasshouse environment, there is practically no information available on the effects of temperature on nodulation of legumes and resultant nitrogen fixation. The most pertinent work was

performed by Jones and Tisdale (1921). The absence of nodulation of soybean at 40 deg. C. in their experiments could well have been because of death of the legume bacteria as well as the effect of high soil temperatures on the plant. Control of abnormally high temperatures must be taken into consideration in glasshouse experiments with legumes.

Within each inoculation grouping, variation in temperature tolerance occurs, and the glasshouse trial on *Centrosema pubescens* indicates that selection of strains tolerant to high temperatures is of possible practical use. The result of further selecting mutants within a strain is now being studied.

Bisset (1952) described endospore formation in the genus *Rhizobium*. Here rests a mechanism for resistance to high-temperature exposure. Great variation between strains in their ability to produce endospores apparently exists—for example, pea and clover rhizobia are claimed to form them only rarely, while rhizobia from other legumes form them more commonly. Furthermore, Bisset stated that as a rule infection occurs only through the agency of variants of typical morphology (heat-susceptible), these being derived from atypical phases (i.e., sporogenous and heat-resistant) either spontaneously or by contact with seedling plants. Selection of strains with sporogenous phases therefore may be a practical aid to overcoming the harmful effects of high soil temperatures. The success of the method would depend on the rate of reversion to the infective type with respect to the duration of high soil temperatures in the course of seed germination.

The concentration of inoculum applied also has an effect. However, the questionable economic practicability of farmers applying inoculum at approximately 100 times the normal concentration limits the value of this approach.

Greater control of the temperature effect may be achieved by agronomic practice. Decreasing temperature with increasing depth of soil suggests that increase of planting depth would overcome high temperature effects. This is limited by a number of factors, including seed size and soil physical properties. The shallow planting necessary with small-seeded legumes makes such legumes more susceptible not only to high soil temperatures near the surface but also to fluctuating surface soil moisture conditions.

Planting into the shade of vegetation, either native pasture or planted pasture, and covering with trash are effective ways to control high temperatures in the surface 2 in.

The season of planting and the time of day at which planting is done are important considerations. The practice in many parts of Queensland is to plant winter pasture species such as red clover and white clover on late summer rains. Under such conditions, trouble could be encountered.

The time required to eliminate or to seriously impede nodulation by the legume bacteria on the seed of *C. pubescens* inoculated at normal concentrations and held at 40 deg. C. varied in the glasshouse trial from three to six hours depending on the bacterial strain. With a soil rising to a temperature of 45-47 deg. C. at planting depths, the time would be expected to be much less. On days when trouble is likely to occur, planting should be carried out as late in the day as practicable. Planting late in the day, however, provides no real guarantee that the trouble will be overcome.

With *C. pubescens* in sterile soil at 28 deg. C. some multiplication occurs outside the seed before germination. Counts indicated a population of viable organisms per seed, under these conditions, of $1{\cdot}4 \times 10^3$, 4×10^3, $3{\cdot}1 \times 10^4$ and $3{\cdot}5 \times 10^6$ organisms at 0, 24, 48 and 120 hours after inoculation, respectively. Up to two days after planting this species, seed populations around the seed are therefore low enough to be killed quickly by possible soil temperatures. With fluctuating soil temperature and less ideal field conditions, it may be expected that this danger period would be increased considerably.

Indications are (Fred, Baldwin and McCoy 1932) that the rate of spread of rhizobium through the soil is very slow indeed. The quickest line of migration from the rigorous soil surface conditions is along the root after root emergence. Therefore, up to this time the rhizobia will remain more or less around the seed. The time for root emergence varies from species to species. For *C. pubescens* it is 4–7 days for normal seeds, hard seeds taking longer. With some species of *Trifolium* and *Medicago,* emergence of the root will occur within two days.

To sum up, selection of bacterial strains which require a longer exposure to high temperatures for complete kill may be of some use, but this may have to be supplemented by agronomic practices such as planting into shade of existing grasses or natural vegetation and other methods which aim at lowering soil temperatures, rather than overcoming the effect of high soil temperature itself. The practice of sod-seeding may have an added value for this reason.

VI. ACKNOWLEDGEMENTS.

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APPENDIX 1.

MAXIMUM TEMPERATURES FOR GROWTH OF *Rhizobium* SPP.

Host.	Strain Number.	Source.	Maximum Temperature for Growth (°C.).	Latitude of Isolation (°S.).
A. Medic Cross-inoculation Group				
Medicago hispida Gaertn. ..	QA685 ..	Gatton	38·5	27·5
M. sativa L.	QA383 ..	Rothamsted (England) AH	40	
	QA679 ..	Archerfield	36·5	27·5
	QA681 ..	Gin Gin	42·5	25
	QA682 ..	Rockhampton	42·5	23
	QA683 ..	Theodore	42·5	24·5
M. tribuloides Desr.	QA684 ..	Cecil Plains	42·5	27·5
B. Trifolium Cross-inoculation Group				
Trifolium incarnatum L. ..	QA795 ..	Sydney University SU297	32	
	QA790 ..	Sydney University SU298	31	
T. pratense L.	QA382 ..	Rothamsted Clover F ..	32·7	
	QA516 ..	Kingaroy	32·7	26·5
	QA859 ..	Tasmania TAI	32	
T. repens L.	QA444 ..	Lismore	32·7	
	QA483 ..	Kingaroy	32·7	26·5
	QA474 ..	Kingaroy	38·5	26·5
T. subterranean L.	QA442 ..	New South Wales NA34 ..	34·6	
C. Pea Cross-inoculation Group				
Pisum sativum L.	QA384 ..	Rothamsted HX	32·7	
	QA794 ..	Sydney University SU302	32	
D. Tropical Legume Miscellany				
Arachis hypogea L.	QA354 ..	Brisbane	35	27
	QA376 ..	University of Wisconsin ..	33·8	
	QA607 ..	U.S.D.A.	37	
	QA769 ..	Sydney University ..	37	
	QA787 ..	Sydney University SU319	35·5	
Cajanus cajan (L.) Millsp. ..	QA375 ..	University of Wisconsin ..	35·6	
Cassia chamaecrista L. ..	QA634 ..	U.S.A.	33	
Centrosema plumieri (Turp.) Benth.	QA811a	Malaya	35·2	
	QA813 ..	Brisbane	36·5	27
C. pubescens Benth.	QA522 ..	Atherton Tableland ..	42	17
	QA523*a*	Atherton Tableland ..	35	17
	QA853 ..	Atherton Tableland ..	35·2	17
	QA859 ..	Atherton Tableland ..	36·5	17
	QA835 ..	Atherton	35·2	17
	QA616, 1a	Cairns	35·2	17
	QA616, 2a	Cairns	34	17
	QA837 ..	Ayr	32·1	19
	QA838 ..	Ayr	35·2	19
	QA856 ..	Ayr	36·6	19
	QA549 ..	Innisfail	38·5	20
	QA851 ..	Innisfail	33	20
	QA843 ..	Mackay	36·5	21
	QA844 ..	Mackay	36·5	21
	QA848 ..	Rockhampton	38·5	23

APPENDIX 1.—continued.

Host.	Strain Number.	Source.	Maximum Temperature for Growth (°C.).	Latitude of Isolation (°S.).
C. pubescens Benth.—*cont.* ..	QA849 ..	Rockhampton	36·5	23
	QA852 ..	Rockhampton	35·2	23
	QA858 ..	Rockhampton	33·9	23
	QA841 ..	Moolboolaman	36·5	25
	QA842 ..	Moolboolaman	35·2	25
	QA733 ..	Coolum	36·6	26
	QA855 ..	Currumbin	35·2	28
	QA602 ..	U.S.D.A.	35·6	
	QA723 ..	Japan	36·6	
	QA687 ..	Rubber Research Institute, Malaya 272	38	
C. virginianum (L.) Benth.	QA860 ..	U.S.D.A.	35·5	
Clitoria ternatea L.	QA560 ..	Atherton Tableland ..	33	17
	QA606 ..	U.S.D.A.	38	
Crotalaria intermedia Klotschy	QA863 ..	Redland Bay (CB188) ..	41·4	27
C. sagittalis L.	QA642 ..	U.S.A.	35·6	
Cytisus proliferus L.f. ..	QA715 ..	Toowoomba	33	27
Desmodium uncinatum (Jacq.) DC.	QA623 ..	Coolum	32	26·5
D. sessilifolium (Torr.) Torr. & Gray	QA638 ..	U.S.A.	39·5	
Desmodium sp.	QA780 ..	Brisbane	31	27
Glycine javanica L.	QA619, 2a	Coolum	35·2	26·5
Glycine max (L.) Merrill ..	QA597 ..	U.S.D.A.	33·8	
	QA598 ..	U.S.D.A.	38	
	QA647 ..	U.S.A.	33	
	QA648 ..	U.S.A.	35·6	
Indigofera endecaphylla Jacq.	QA861 ..	Beerwah (CB33)	32	27
I. australis Willd.	QA468 ..	Kingaroy	30·5	27
Lespedeza striata Hook. & Arn.	QA604 ..	U.S.D.A.	36	
	QA375 ..	University of Wisconsin ..	32	
	QA765 ..	Sydney University ..	38	
	QA766 ..	Sydney University ..	32	
	QA768 ..	Sydney University ..	30	
Lotus australis Andr. ..	QA865 ..	Rodds Bay (CB440) ..	35·5	24
Mucuna utilis Wall.	QA603 ..	U.S.D.A.	33	
Phaseolus lathyroides L. ..	QA629 ..	Coolum	32	26·5
	QA862 ..	Calliope	35·5	24
P. radiatus L.	QA601 ..	U.S.A.	34	
Psoralea eriantha Benth. ..	QA864 ..	Charleville (CB362) ..	38	27
Pueraria phaseoloides (Roxb.) Benth.	QA548b	Innisfail	34	20
	QA600 ..	U.S.D.A.	32	
Pultenaea villosa Willd. ..	QA323 ..	Brisbane	35·6	27
Sesbania aculeata Auct. Austral.	QA866 ..	Richmond (CB294) ..	38	20·6
Vigna sinensis (L.) Endl. ex. Hassk.	QA314 ..	Brisbane	37	27
	QA608 ..	Grantham	35·6	27
	QA113 ..	Queensland	37	

APPENDIX 2.

NUMBERS OF PLANTS WITH NODULES IN GLASSHOUSE TRIAL.

Treatment.			Replication.						Percentage of Plants Nodulated.
Strain.	Concentration.	Hours.	I.	II.	III.	IV.	V.	VI.	
QA837	Low	0	8 (9)	9 (10)	10 (10)	10 (10)	9 (11)	8 (8)	93·1
		3	3 (10)	5 (7)	4 (15)	3 (7)	0 (4)	2 (6)	34·7
		6	0 (16)	5 (12)	0 (9)	1 (10)	0 (14)	0 (10)	8·5
		9	0 (15)	0 (11)	0 (7)	0 (12)	0 (13)	2 (9)	3·0
QA837	High	0	8 (9)	10 (10)	6 (7)	10 (13)	8 (8)	8 (8)	90·9
		3	6 (7)	4 (10)	7 (11)	4 (8)	0 (13)	6 (11)	45·0
		6	4 (10)	3 (14)	0 (14)	2 (11)	1 (11)	0 (9)	14·5
		9	0 (5)	5 (8)	0 (11)	1 (11)	7 (9)	6 (8)	36·6
QA549	Low	0	8 (8)	13 (16)	11 (12)	13 (14)	10 (10)	8 (9)	91·3
		3	4 (5)	12 (14)	13 (15)	6 (8)	7 (10)	10 (11)	82·5
		6	0 (11)	3 (11)	0 (12)	0 (9)	5 (10)	8 (13)	24·2
		9	2 (15)	2 (9)	2 (8)	5 (10)	4 (6)	1 (8)	28·6
QA549	High	0	7 (7)	8 (9)	10 (11)	8 (10)	9 (10)	7 (12)	83·1
		3	10 (10)	9 (12)	8 (14)	10 (10)	8 (9)	9 (10)	83·1
		6	5 (7)	10 (15)	10 (12)	6 (10)	12 (15)	15 (15)	78·4
		9	9 (11)	8 (9)	11 (11)	11 (14)	12 (15)	9 (13)	82·2

Figures in parenthesis refer to the number of plants per plot.
Low concentration = 1 x 10^3 organisms per seed.
High concentration = 1 x 10^6 organisms per seed.

SUMMARY—MEAN VALUES AND SIGNIFICANT DIFFERENCES IN PERCENTAGE OF PLANTS WITH NODULES.

Transformed Means.

—		Concentration.		Strain.		Means.
		L	H	QA837	QA549	
Times—	0	76·8	74·0	77·4	73·4	75·4
	3	48·9	57·0	37·6	68·4	53·0
	6	15·6	41·0	14·0	42·6	28·0
	9	19·0	49·9	18·3	50·6	34·4
Strain—	QA837	31·0	42·6			36·8
	QA549	49·2	68·3			58·7
Means		40·1	55·5	36·8	58·7	47·8

Equivalent Mean Percentages.

		Concentration.		Strain.		Means.
		L	H	QA837	QA549	
Times—	0	94·8	92·4	95·2	91·8	93·6
	3	56·8	70·3	37·2	86·4	63·8
	6	7·2	43·0	5·8	45·8	22·5
	9	10·6	58·5	9·9	59·7	31·9
Strain—	QA837	26·5	45·0			35·9
	QA549	57·3	86·3			73·0
Means		41·5	67·9	35·9	73·0	–

Means.	Strain Equivalent.	Necessary Difference.	
		5%.	1%.
Concentrations v. Times	4·82	13·6	18·0
Strains v. Times	4·82	13·6	18·0
Concentrations v. Strains	3·41	9·6	12·8

Interactions of Strains x Times and Concentrations x Times are highly significant.

APPENDIX 3.

AVERAGE NODULE NUMBERS PER PLANT IN GLASSHOUSE TRIAL.

Treatment.			Replication.			
Strain.	Concentration.	Hours at 40°C.	I.	II.	III.	IV.
QA837	Low ..	0	4·2	3·4	4·9	3·5
		3	0·9	1·6	0·5	0·7
		6	0	1·2	0	0·2
		9	0	0	0	0
	High ..	0	3·8	3·7	2·6	1·9
		3	1·4	1·2	1·9	0·9
		6	1·6	1·2	0	0·3
		9	0	5·9	0	0·1
QA549	Low ..	0	6·5	3·5	7·6	4·4
		3	4·4	2·5	2·5	3·1
		6	0	0·9	0	0·9
		9	0·6	0·7	1·6	2·2
	High ..	0	4·7	4·6	3·5	2·8
		3	3·5	2·5	2·8	4·5
		6	6·6	2·9	4·2	4·5
		9	2·3	5·4	3·4	3·4

Low concentration = 1 x 10^3 organisms per seed.
High concentration = 1 x 10^6 organisms per seed.

SUMMARY—MEAN VALUES AND SIGNIFICANT DIFFERENCES AVERAGE NUMBER OF NODULES/PLANT.

Transformed Means.

		Concentration.		Strain.		Means.
		L	H	QA837	QA549	
Times—	0	·75	·64	·64	·74	·69
	3	·44	·50	·32	·62	·47
	6	·09	·48	·16	·40	·28
	9	·17	·44	·11	·50	·30
Strain—	QA837	·27	·35			·31
	QA549	·45	·67			·56
Means		·36	·51	·31	·56	·44

Equivalent Mean Numbers.

		Concs.		Strain.		Means.
		L	H	QA837	QA549	
Times—	0	4·62	3·37	3·37	1·50	3·90
	3	1·75	2·16	1·09	3·17	1·95
	6	·23	2·02	·44	1·51	·90
	9	·48	1·75	·29	2·16	1·00
Strain—	QA837	·86	1·24			1·04
	QA549	1·82	3·68			2·63
Means		1·29	2·24	1·04	2·63	–

Means.	Strain Equivalent.	Necessary Difference.	
		5%.	1%.
Concentrations v. Times	·053	·15	·20
Strains v. Times	·053	·15	·20
Concentrations v. Strains	·038	·11	·14

Interaction of Concentrations x Times is highly significant.

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A STUDY OF THREE IMPORTANT PASTURE MIXTURES IN THE QUEENSLAND SUBTROPICS

PROGRESS REPORT, 1955–1958.

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SUMMARY.

The first four years' results of a grazing trial of three pasture mixtures are presented. The mixtures were Rhodes grass, green panic and Gayndah strain buffel grass, each sown with Hunter River lucerne and phasey bean.

All mixtures carried beef cattle at a heavy rate through a severe drought, and during seasons of good rainfall uninterrupted liveweight increases through the winter occurred. Animal weight gains on the Rhodes grass-legume mixture were inferior to those on the other mixtures.

The liveweight increases per acre on sown pastures were more than three times as great as those on native pasture grazed continuously at the rate normal for the district, which was half the stocking intensity of the sown pastures.

The buffel grass-legume pasture produced the highest yields of dry matter and of crude protein. Consistent differences occurred in the crude protein status of the grass components in each mixture, the order being green panic, buffel grass and Rhodes grass.

The value of Hunter River lucerne in all mixtures was demonstrated and its ability to persist under rotational grazing confirmed.

Seasonal pasture productivity trends and liveweight changes are discussed. Of the pasture indices considered, the legume crude protein yield bore the closest relationship to liveweight changes.

I. INTRODUCTION.

Rhodes grass (*Chloris gayana*), green panic (*Panicum maximum* var. *trichoglume*) and Gayndah strain buffel grass (*Cenchrus ciliaris*) are widely used sown pasture species in subtropical Queensland. Extensive monospecific sowings of all three grasses have been made in country which originally carried a canopy of closed softwood or brigalow (*Acacia harpophylla*) scrub associations. Buffel grass has also been sown extensively in the cleared gidyea (*A. cambagei*) scrubs of central-western Queensland. Relatively small areas have been developed in the extensively ringbarked eucalypt forest country, which is still largely under native pasture. Little information exists on the relative merits of the three species when sown in association with legumes on a prepared seedbed on the one soil type.

Marked seasonal fluctuations in the protein status of grasses occur throughout the Queensland subtropics. When soil moisture is not a limiting factor, the yield and the protein content of the pasture grasses during the spring, summer and autumn are sufficient for weight gains in beef cattle. Frosts cause a cessation of pasture growth and result in a general decline of protein to a level barely adequate for maintenance. In years of low rainfall, the bulk of pasture available to stock may also be insufficient. However, a period of low protein levels which is independent of rainfall generally exists during at least the three winter months.

Christian and Shaw (1952) showed the benefits derived by two experimental Rhodes grass pastures from the association of lucerne, but the persistence of this legume in a grazed pasture on eucalypt forest soils in the Burnett region had not been demonstrated. The subtropical phasey bean (*Phaseolus lathyroides*) had also given promise as a pasture legume in south-eastern Queensland, but its value as a component of pasture was unknown.

A grazing trial of grass-legume mixtures was laid down on "Brian Pastures" Pasture Research Station, Gayndah, which is owned by the Australian Meat Board and operated by the Department of Agriculture and Stock. The object of the trial was to compare the productivity of three grass-legume mixtures. The grasses used were commercial Rhodes grass, commercial green panic and Gayndah strain buffel grass, and each was sown with lucerne and phasey bean. The assessment was made in terms of liveweight gains of beef cattle and of pasture growth, protein status and persistence.

II. EXPERIMENTAL PROCEDURE

(1) Design.

The three treatments were sown with commercial seed at the following rates.—Rhodes grass 6 lb. per acre; commercial green panic and Gayndah strain buffel grass, each 5 lb. per acre; Hunter River lucerne 1 lb. per acre; and phasey bean 0.5 lb. per acre.

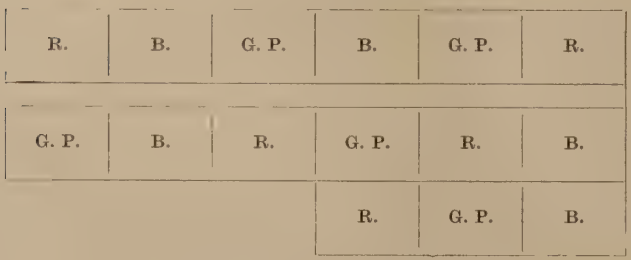

Fig. 1.

Diagram of Design.

A split plot design was employed. Five sub-plots, each of four acres, were sown to each treatment, the sub-plots being arranged at random in five blocks each containing three sub-plots (Fig. 1). All blocks were grazed rotationally on the basis of 2 weeks' grazing and 8 weeks' spell.

The trial was established on heavy-textured, basalt-derived, brown clay soils of good fertility carrying native pasture, the predominant species being bunch spear grass (*Heteropogon contortus*), forest blue grass (*Bothriochloa intermedia*) and other blue grasses (*Dichanthium* spp.).

(2) Establishment of the Pasture.

All plots were sown in January–February 1954, on land which had been prepared by ploughing and harrowing. Initial establishment was best in the Rhodes grass treatment. Two sub-plots of both buffel grass and green panic which failed to establish satisfactorily were resown in January 1956.

(3) Management.

Experimental grazing commenced in January 1955 with five 2-year-old steers of 600 lb. liveweight per treatment. From September 1956, eight weaner steers per treatment were employed. All cattle were matched into approximately equal groups by a random selection based on previous liveweights.

Up to the end of 1958 six groups had been depastured on the trial, as listed in Table 1.

Table 1.

STOCKING SEQUENCES.

Group.	Date of Commencement of Grazing.	Duration of Trial. (Weeks.)	Description.
1.	Jan. 7, 1955	54	5 2-year-old Hereford steers, initial average liveweight 605 lb., per treatment of 20 acres
2.	Jan. 20, 1956	18	5 forward store Hereford steers aged 34 months, initial average liveweight 903 lb., per treatment of 20 acres
3.	May 11, 1956	20	5 forward store Hereford steers aged 30 months, initial average liveweight 888 lb., per treatment of 20 acres
4.	Sept. 14, 1956	64	8 weaner Hereford steers aged 9–10 months, initial average liveweight 421 lb., per treatment of 20 acres
5.	Nov. 22, 1957	40	8 weaner Hereford steers aged 12 months, initial average liveweight 363 lb., per treatment of 20 acres
6.	Aug. 15, 1958	..	8 weaner Hereford steers aged 9 months, initial average liveweight 411 lb., per treatment of 20 acres

At the commencement of the trial with Group 1, a shortened rotation of 2 weeks' grazing, 4 weeks' spell, using only three blocks, was adopted, as two blocks were not considered ready for grazing. This shortened cycle was again used in January–March 1956, when two blocks were withdrawn from grazing and the buffel grass and green panic sub-plots oversown.

From mid-December 1956 to mid-February 1957, all blocks were mown to remove a large bulk of dead material accumulated from the previous season's growth. Hay of low quality was conserved from mowings which were made immediately after stock had been removed from each block. This hay was fed back to appropriate sub-groups at 12 lb. per head per day for five months of the 1957 drought.

(4) Records.

(a) Pasture Yields.

Forty 5 link x 5 link quadrats were cut at ground level in each sub-plot immediately prior to grazing. The pasture components were separated into sown grass, lucerne, phasey bean, and other species, dried and weighed. Yields of forage, percentage moisture and crude protein were determined from the sub-samples.

From July 1956 the sampling intensity was reduced to 30 quadrats per sub-plot, but an additional sampling was made immediately after grazing to provide estimates of consumption during the grazing period and the growth in excess of deterioration of the various species during the protected phase.

(b) Cattle Weights.

Cattle weights were recorded fortnightly following 16 hours' fasting immediately before each grazing period. A group of steers of similar age and of comparable weight were depastured in the Station bullock paddock adjacent to the trial area. These cattle were weighed monthly with other Station cattle, and indicated the growth pattern to be expected of steers of similar age on native pasture under normal Station management (continuous grazing and annual burning).

III. SEASONAL CONDITIONS.

The climate is subtropical, with a mean annual rainfall of 30 in. of predominantly summer incidence. Some 9 in. are recorded in the six winter months. Daily maximum temperatures greater than 95 deg. F. occur quite frequently. The mean January and July temperatures are 78·0 and 56·5 deg. F. respectively.

The main growing period of the sown grasses is usually January–March, but when soil moisture is adequate good growth occurs from October and may continue till early May if temperatures permit. Light frosts can occur from mid-April. Heavy frosts are experienced in late June–July with grass recordings as low as 20 deg. F., resulting in cessation of growth and frosting of the summer-growing grasses.

Abnormal fluctuations in rainfall have occurred since the commencement of the trial, as shown in Table 2.

Table 2.

Monthly Rainfall (inches) at "Brian Pastures" from January 1954 to August 1958, and Mean Values for Gayndah, 1870–1956.

Month.	"Brian Pastures."					Gayndah. Mean. 1870–1956.
	1954.	1955.	1956.	1957.	1958.	
January	Nil	·75	3·14	1·18	3·36	4·70
February	9·51	3·43	8·29	·31	8·15	4·20
March	·37	9·65	10·15	·46	2·78	3·10
April	·40	4·17	1·57	·05	1·39	1·46
May	·25	4·56	2·42	·00	·11	1·55
June	·70	·50	2·35	·73	5·99	1·82
July	9·21	1·84	2·14	1·96	·17	1·47
August	2·22	·12	·33	1·04	1·57	1·12
September	1·56	2·43	·23	·00	1·51	1·47
October	2·30	2·11	2·50	·89	—	2·37
November	4·21	1·26	1·77	1·37	—	2·97
December	1·33	5·29	9·93	1·17	—	4·21
Total	32·06	36·06	44·85	9·16		30·44

IV. RESULTS.

(1) Pasture Yields.

(a) Total Dry Matter.

Marked seasonal changes in the amount of available forage present before grazing occurred in all treatments, as shown in Fig. 2. These curves were calculated from the moving means of five successive samplings. The actual growth of the pasture was even more seasonal, and for five months from early May in 1955 production during the 8-weeks' protected phase failed to satisfy the appetites of the stock which were dependent for at least a portion of their diet on standing feed produced during the previous summer–autumn.

For the first 14 months the Rhodes grass mixture produced more total dry matter than the other treatments, but by the end of the second summer the green panic and buffel grass mixtures were both outyielding the Rhodes grass mixture. The deterioration of Rhodes grass during the winter and spring of the second year was slower than that of the other grasses and Rhodes grass yielded more forage, but this was of very low quality.

Peak yields of fodder available before grazing occurred in the autumn of the second year, when 3,200, 3,400 and 4,000 lb. dry matter per acre were present in the green panic, Rhodes grass and buffel grass plots respectively.

Mowing drastically reduced available forage during February–May 1957, and steers grazing Rhodes grass had a slight advantage in total feed. With no effective rainfall in this period a steady decline in pasture yields occurred into midwinter, and the low quality hay from the December–February cut was fed back during this period, adding to the bulk consumed but making little contribution to the digestible protein intake.

Two inches of rain in July and a further inch in August produced a rapid though short-lived response in both green panic and buffel grass; Rhodes grass remained quiescent. At the end of the drought, samplings at ground level showed the total amount of forage available to be of the order of 80–120 lb. dry matter per acre present before grazing.

The recovery of buffel grass and green panic from drought was excellent. Three weeks after rain fell in mid-January 1958 these species had produced fresh growth in excess of appetite requirements. This effect is illustrated in Fig. 2. Rhodes grass had a high degree of mortality, and the few surviving crowns made poor regrowth. Data to illustrate this response are presented in Table 3.

Table 3.

Growth Rate of Grass Components.

Expressed as Pounds of Air-dry Matter per Acre.

8-weeks Period Ending.	Rhodes Grass.			Green Panic.			Buffel Grass.		
	Sub-plot.	Growth per Day.	Available Feed.	Sub-plot.	Growth per Day.	Available Feed.	Sub-plot.	Growth per Day.	Available Feed.
3–1–58 ..	11	3·5	351	10	−0·6	26	12	3·2	373
17–1–58 ..	13	−0·8	332	14	−0·02	21	15	1·4	239
31–1–58 ..	1	−0·02	194	3	−2·5	189	2	4·7	474
14–2–58 ..	6	−2·8	2	5	8·8	561	4	16·4	1,059
28–2–58 ..	9	−0·8	46	7	8·9	504	8	16·7	981
14–3–58* ..	11	3·1	374	10	9·3	532	12	25·9	1,540
14–3–58* ..	13	3·9	301	14	9·9	417	15	20·1	1,157
28–3–58 ..	1	0·8	67	3	24·7	1,154	2	39·4	2,116
11–4–58 ..	6	2·8	132	5	41·9	2,157	4	46·1	2,691
25–4–58 ..	9	3·4	215	7	11·2	1,016	8	31·3	2,341

* One block mown for hay.

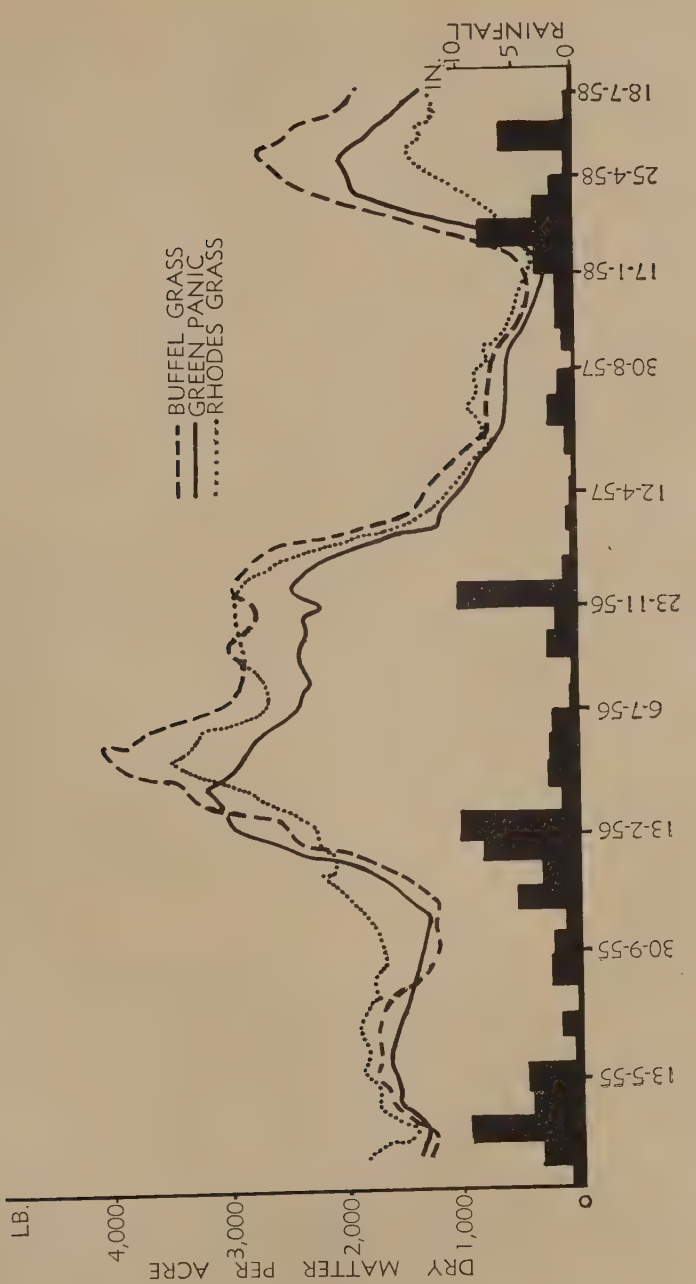

Fig. 2.

Total Dry Matter Yield of Pasture Mixtures at Sampling Before Grazing. Rainfall records are given in histogram form.

(b) Lucerne.

The effect of initial competition from Rhodes grass on the density of lucerne was evident until the spring of 1957. Lucerne yields increased under rotational grazing to a peak in the late spring of 1956 of the order of buffel grass 450, green panic 380 and Rhodes grass 220 lb. dry matter per acre present before grazing (Fig. 3). In years of adequate rainfall, lucerne made most rapid growth during September–October, the lucerne : grass ratio always increasing at this time. The 8-weeks' protected phase permitted seasonal seeding, and natural regeneration occurred.

In 1957 a prolific lucerne germination occurred in August–September during the drought following late winter rain. A greater amount of surface trash in all Rhodes grass plots, coupled with much stronger competition from the grasses in the other two treatments, resulted in marked differences in lucerne seedling survival. Many seedlings in the Rhodes grass plots survived, while the majority in the other two treatments succumbed. With an accompanying general decline of the older established lucerne in both buffel grass and green panic as the drought progressed, the greatest lucerne yields in 1958 were recorded in the Rhodes grass treatment.

While an overall decline in yield was recorded, the performance of lucerne throughout the driest year on record was outstanding. All forage produced was consumed to ground level at each grazing period, the small regrowth produced during each spell being eagerly sought by stock. Valuable though short-lived responses occurred to rains falling during the drought period. The surviving crowns responded vigorously after drought-breaking rain but the regrowth was almost defoliated by jassids, black spot, anthracnose and stem and leaf rusts. However, subsequent winter and spring growth was good, and yields varied from 70 to 100 lb. dry matter per acre in the spring of 1958. With a basal cover of 0·5 per cent., lucerne yielded sufficiently well to provide for the total appetite requirements of all stock for the grazing periods occurring during the flush spring growth periods. In spite of this, no symptoms of bloat were recorded.

(c) Phasey Bean.

Establishment of this legume was satisfactory and density increased to provide yields in excess of 4 cwt. dry matter per acre in the autumn of the second year (1956). Stock deferred grazing until after seed had been set, young plants seeming less palatable. In the first two years the plant provided high-protein fodder in late autumn, but regeneration during December 1956 was poor in spite of good soil moisture. Phasey bean provided negligible winter grazing in all years, being almost completely defoliated by frost.

(d) Intrusion of Native Species.

The greater proportion of native species, principally *Dichanthium* spp., present in the green panic and buffel grass treatments was largely due to the poorer initial establishment and the tussocky habit of these sown species.

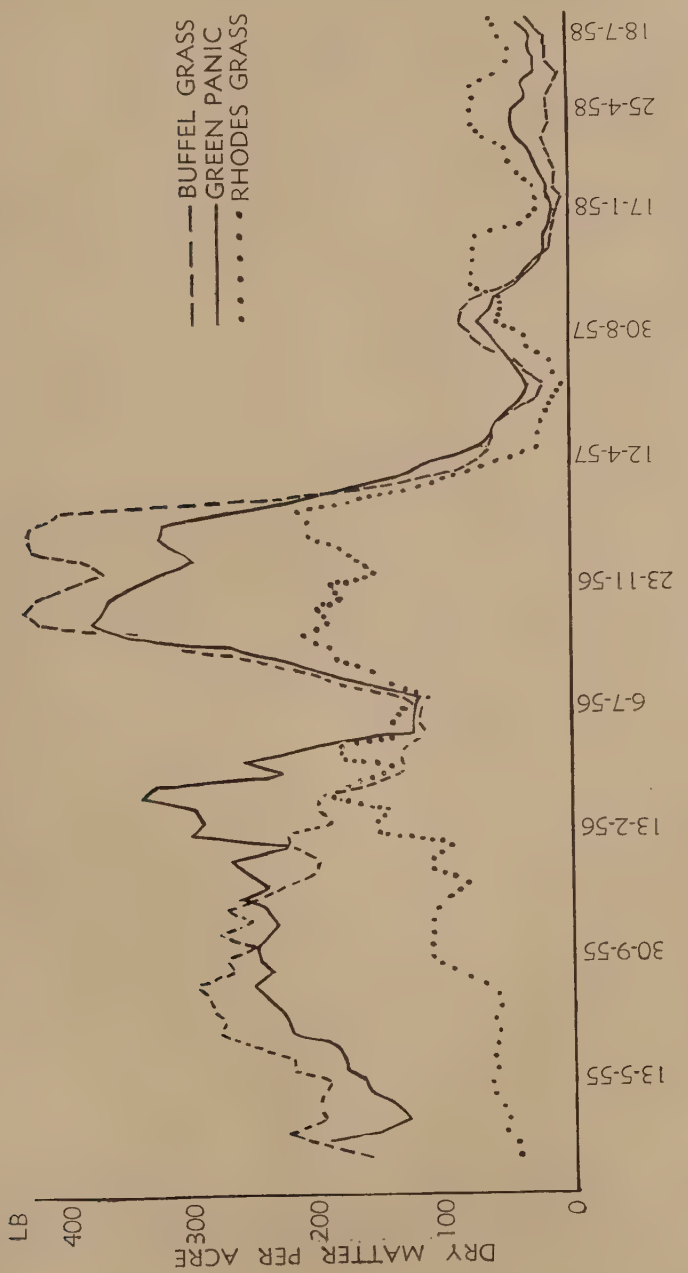

Fig. 3.

Dry Matter Yield of Lucerne in Pasture Mixtures. Moving means are plotted.

To measure the effect of the severe drought of 1957 on persistence, botanical surveys were conducted to estimate percentage basal cover. The point quadrat method was employed and surveys were conducted during January 1958, when all plots were under peak drought stress, and in September 1958, some eight months after the drought had broken.

Total basal cover declined from 8·8 to 4·9, 8·2 to 6·8 and 6·6 to 6·2 per cent. in the Rhodes grass, buffel grass, and green panic treatments respectively. All sown grasses declined in basal cover, Rhodes grass the most severely. The following changes in basal cover of the grasses were recorded:— Rhodes grass from 6·5 to 1·4 per cent., buffel grass from 5·3 to 3·7 per cent., and green panic from 3·3 to 2·6 per cent. Some increases were registered in native species but much of this increment was due to ephemeral herbage, such as *Coronopus didymus, Plantago varia* and *Calotis cuneata.* Native species of *Dichanthium* declined slightly in cover over the period, and their regrowth following drought-breaking rains was inferior to that of the sown species.

(2) Protein Content.

Seasonal changes in the crude protein content of the pasture available before grazing are shown in Fig. 4. The percentage of protein was closely related to the lucerne contribution, which reached spring peaks of 70–80 lb. crude protein per acre in the green panic and buffel grass mixtures and 40 lb. crude protein per acre in the Rhodes grass mixture. Consistent differences occurred in the crude protein content of the grass components, green panic being superior to buffel grass, which was superior to Rhodes grass. The lower yield of lucerne in the Rhodes grass plots further reduced the crude protein content of the mixture until the break of the drought, when the rise in the lucerne-grass balance increased pasture quality in this treatment.

The total crude protein yield per acre (Fig. 5), being a function of percentage crude protein and total dry matter, showed seasonal fluctuations. The Rhodes grass mixture, with consistently less protein from the grass component, though initially considerably outyielding the other two treatments in total dry matter had less crude protein per acre available. The buffel grass mixture produced the greatest crude protein yield, this being a reflection of its greater bulk, and the percentage crude protein of the mixed pasture was initially superior to that of the green panic mixture. However, the protein status of the green panic mixture was slightly superior after the autumn of 1956, in spite of higher lucerne yields in the buffel mixture.

(3) Animal Liveweight Changes.

Animal growth curves for the good rainfall year of 1955 and the drought year of 1956–57 are presented in Figs. 6 and 7. These curves are drawn from fitted values derived from fifth degree polynomials. Growth curves for the periods 20-1-56–11-5-56 and 11-5-56–14-9-56 are presented in Figs. 8 and 9 respectively. Being of short duration, both these curves are plotted as actual values.

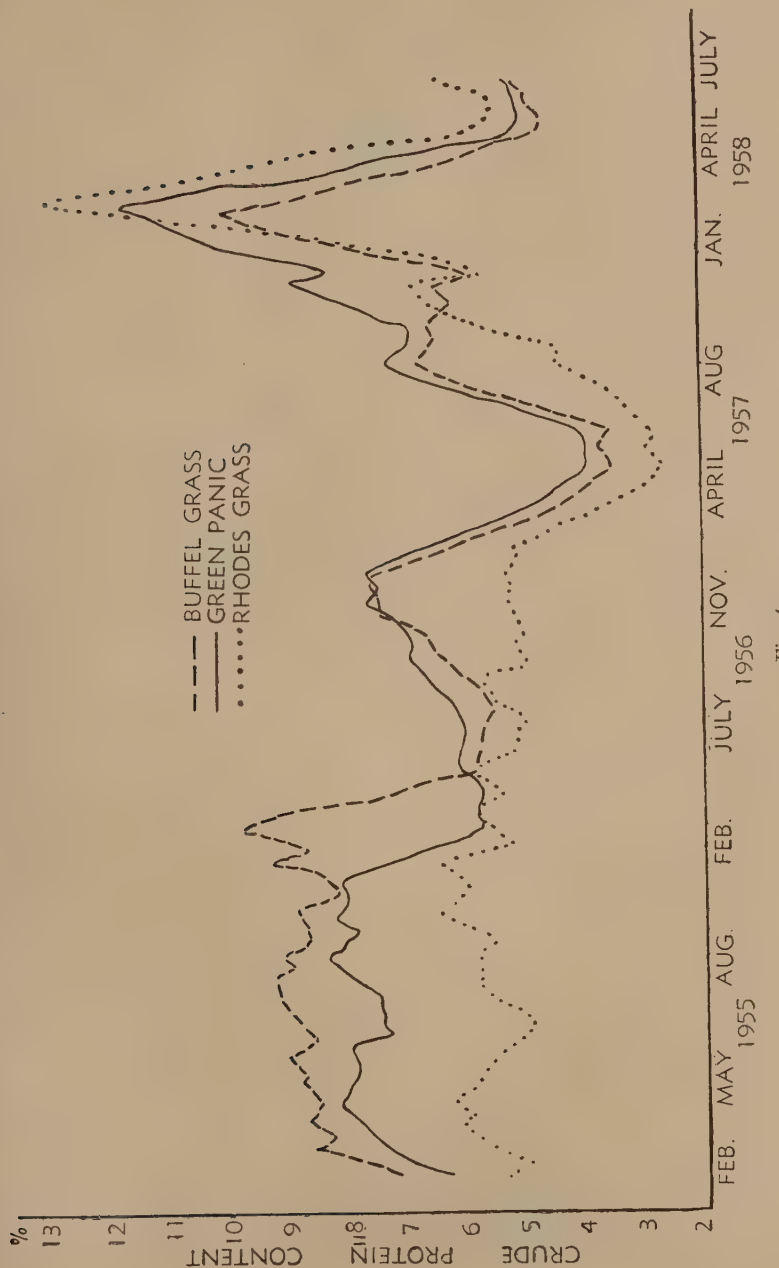

Fig. 4.

Seasonal Changes in Percentage Crude Protein Content of Pasture Mixtures

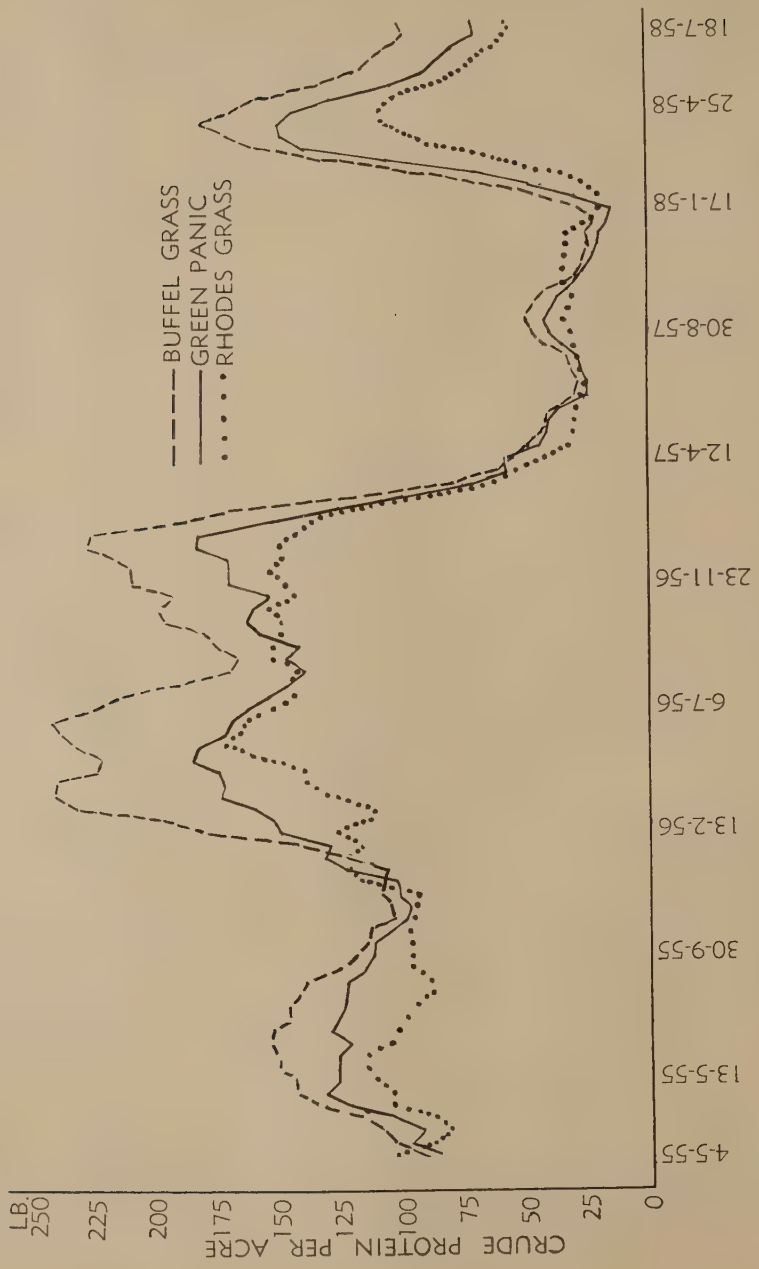

Fig. 5. Crude Protein Yield of Pasture Mixtures. Moving means are plotted.

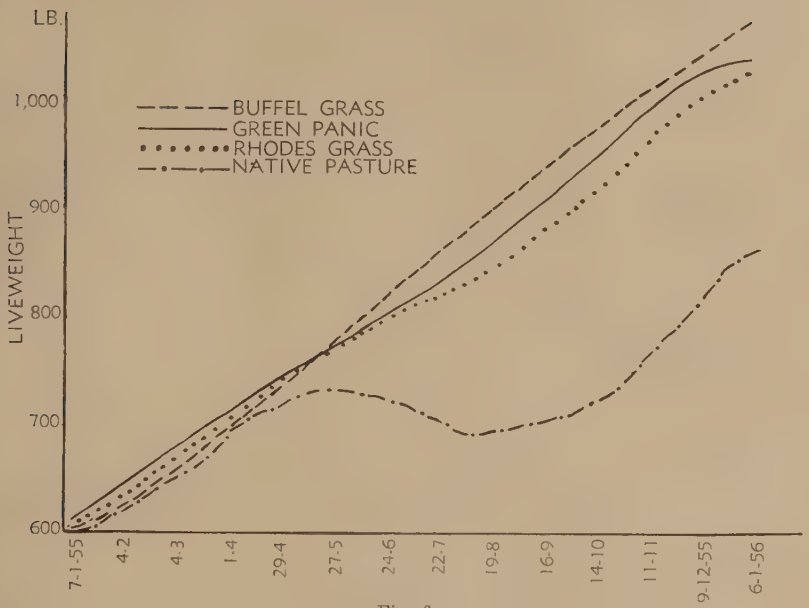

Fig. 6.

Liveweight Changes During 1955, A Year of Good Rainfall.

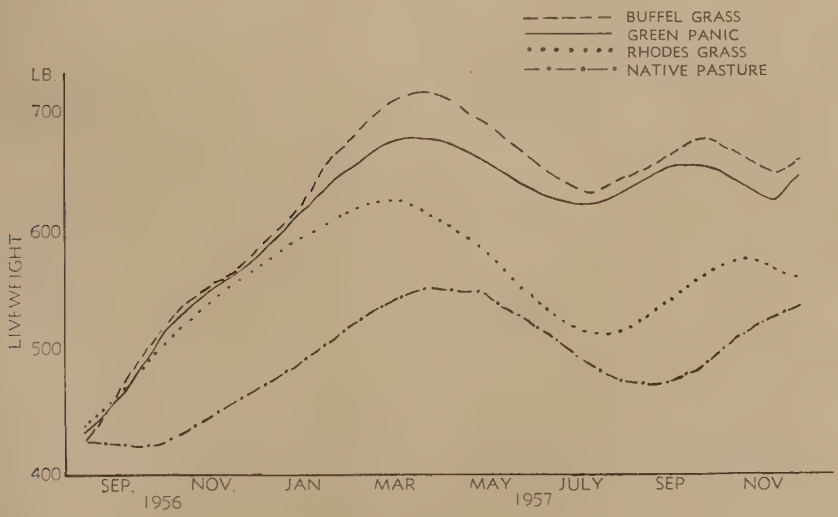

Fig. 7.

Liveweight Changes from Sept. 14, 1956 to Nov. 22, 1957, a Period of Low Rainfall.

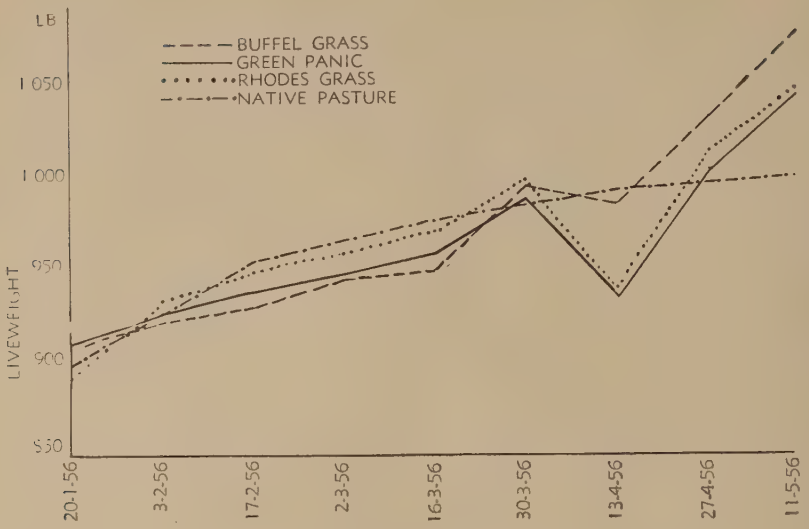

Fig. 8.

Liveweight Changes in the Summer-Autumn of 1956 and 1957.

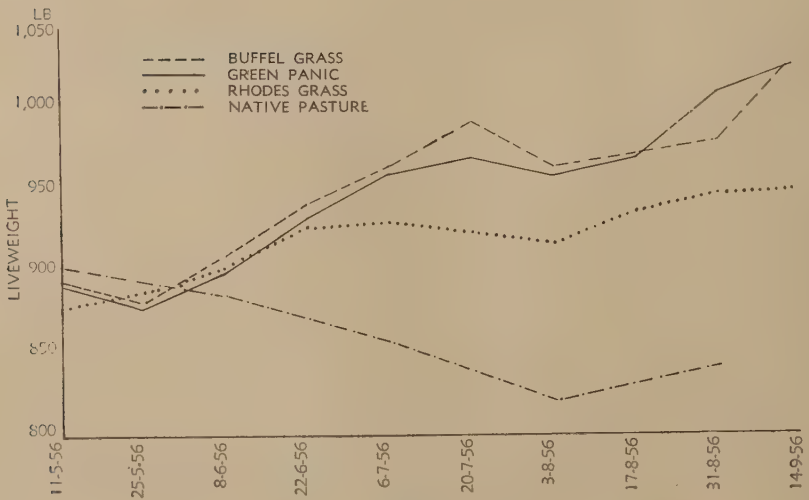

Fig. 9.

Liveweight Changes in the Winter of 1956.

The liveweight data from the first six groups of animals are summarised in Table 4.

Table 4.

WEIGHT CHANGES FOR FIVE GROUPS TURNED OFF THE TRIAL.

Expressed as Pounds Liveweight per Acre.

Group.	Period.	Rhodes Grass Mixture.	Green Panic Mixture.	Buffel Grass Mixture.	Native Pasture.
1.	7–1–55 to 20–1–56	112	116	122	36·5
2.	20–1–56 to 11–5–56	40	34	43	13
3.	11–5–56 to 14–9–56	23	33	34	—7·7
4.	14–9–56 to 22–11–57	51	93	83	25
5.	22–11–57 to 15–8–58	50	65	74	41
	Total..	276	341	356	108

The first groups of 15 steers turned off the trial had an average liveweight of 1,077 lb. at 34 months of age. These cattle dressed with a mean of 58·4 per cent. and graded 8 baby beef and 7 first grade.

One group of forward stores (Group 3) was finished over the period May–September 1956, gaining an average of 120 lb. liveweight during a period when stock on native pasture were losing weight.

From the time of commencement (September 1956), weaner steers made uninterrupted weight gains approximating 1·4 lb. per day during the spring. Rain in December (Fig. 2) enabled this trend to be maintained until April 1957, by which time drought was markedly reducing pasture yield and quality. From this period a general weight loss was recorded until late November, when the next group of weaner steers was depastured. However, all groups recorded a short period of weight gain during the drought, this being a direct reflection of the pasture reaction to July–August rains when both buffel grass and green panic made short growth responses. Early spring growth of lucerne in the Rhodes grass plots provided sufficient high quality forage to enable a slight weight recovery of the steers in this treatment. While these stock were in poor store condition at the time of change, it was possible to maintain the increased stocking rate for the duration of the drought without stock dying.

Cattle responded quickly after drought-breaking rains. Little scouring occurred while they were grazing the lush growth, and weight gains of approximately 2·1 lb. per day were recorded for the first six weeks after rain.

Despite the increased stocking rate, no difficulties with ectoparasites or endoparasites were experienced. Cattle generally carried a low tick burden; this may be a reflection of the rotational management.

In the second half of the period under review the liveweight gain from the Rhodes grass mixture was markedly inferior.

The liveweight changes over the whole period were examined in relation to pasture data, which included changes in the available total dry matter, lucerne dry matter, total protein, lucerne protein, legume protein, percentage crude protein of the pasture, percentage crude protein of grass, and the ratios legume dry matter: total dry matter and lucerne dry matter: total dry matter. Legume crude protein yield bore the closest relationship to liveweight changes.

VI. DISCUSSION.

Despite the inferior overall performance of Rhodes grass, its ease of establishment and early vigour merit attention. Initial establishment of green panic and buffel grass seems critical. Where establishment in the initial year was poor they have not demonstrated ability to colonise fresh areas by successful competition with native grasses. However, both green panic and buffel grass have persisted well, and where early establishment was satisfactory native species have not intruded to any extent.

Rhodes grass seems more frost-tolerant and its autumn growth is superior, but neither the protein yield nor the liveweight gains reflected this. Green panic responded rapidly to rain following moisture stress and to brief warm periods during winter. Its early spring growth was good and surpassed that of buffel grass and Rhodes grass. Buffel grass made its most rapid growth during the hot months of midsummer. The slightly different growth rhythm of green panic and buffel grass suggests that the establishment of separate areas of these two species might be advantageous.

However, the critical factor in animal production was lucerne yield. The wider use of this legume is strongly advocated. Its adaptability to a wide range of climatic and soil conditions is proven and its contribution in increasing the quality of forage has been demonstrated widely. With rotational grazing it has persisted well. Although some decline in lucerne density occurred in the buffel grass and green panic pastures, this followed fairly heavy stocking throughout a bad drought. Observations in 1955 and 1956 showed that seedling regeneration could be expected in years of good rainfall. Sufficient plants were present in the spring of 1958 and further regeneration from seed set in 1958 can be expected. In any event, oversowing is practicable and inexpensive. Lucerne will persist in any of these pastures if some scheme of deferred grazing similar to that reported is practised.

The sown pastures increased productivity, gave good weight gains with young animals, and could ameliorate the seasonal nature of beef turn-off. The question of their best utilisation is important. As stock make adequate liveweight increases on native pasture for five to six months of the year, sown pastures may be better reserved for bridging the nutritional gap of winter and early spring, although this programme may have to be allied with summer conservation.

VII. ACKNOWLEDGEMENTS.

It is a pleasure specifically to record the helpful advice and assistance of Dr. W. A. T. Summerville (Chairman of the "Brian Pastures" Technical Committee), Dr. J. G. Davies (Chief, C.S.I.R.O. Division of Tropical Pastures), and Mr. D. N. Sutherland (Director of Cattle Husbandry, Queensland Department of Agriculture and Stock).

Various officers of the Queensland Department of Agriculture and Stock who have been actively associated with this trial include Messrs. J. K. Cull, T. G. Graham, L. R. Humphreys and S. Marriott. Mr. P. B. McGovern assisted in the design of the trial and treatment of pasture and stock data. The chemical analysis of pasture samples was carried out by Mr. W. R. Winks and other staff members of the Chemical Laboratory.

REFERENCE.

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TRIALS WITH CMU WEEDICIDES IN QUEENSLAND PINEAPPLE PLANTATIONS

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SUMMARY.

Trials were carried out in southern Queensland during 1954-1956 to evaluate parachlorophenyl dimethyl urea (CMU) as a weedicide in pineapple plantations, using sodium pentachlorphenate (PCP) as a standard for comparison.

Consistently better control of weeds was obtained with CMU at 4 lb. per acre than with PCP at 10 lb. per acre. No phytotoxic effects were detectable in pineapples sprayed with CMU at rates up to 8 lb. per acre.

I. INTRODUCTION.

Since 1951, sodium pentachlorphenate (PCP) has been used extensively as a weedicide in Queensland pineapple plantations. As a pre-emergence weedicide, used at the rate of 10 lb. per acre, it is effective and economical. Post-emergence sprays of PCP and emulsifiable oils, however, give only partial control, grasses being particularly resistant. The irritant properties of PCP and associated health hazards are also disadvantageous. There is therefore a need for an alternative weedicide for use in pineapples.

Parachlorophenyl dimethyl urea (CMU) has shown considerable promise overseas as a weedicide capable of exercising some post-emergence control of weeds, including grasses. Its toxicity to warm-blooded animals is stated to be considerably less than that of PCP.

In 1954 a preliminary trial was undertaken at the Maroochy Experiment Station, near Nambour, to compare the weedicidal properties of CMU and PCP and to check the phytotoxicity, if any, of CMU to pineapples. This was followed by a second trial on the Station in 1954–55, and a series of field trials in several districts in 1956.

II. 1954 TRIAL.

In 1954, an experimental sample of CMU as a 50 per cent. wettable powder (under the trade name "AK 100") was obtained. The trial was established in July 1954 in an area of young pineapples on the Maroochy Experiment Station.

Treatments were:—

(A) PCP 10 lb. per acre.

(B) CMU 2 lb. per acre.

(C) CMU 4 lb. per acre.

(D) Control—untreated.

The trial was laid out as 8 x 4 randomised blocks with plots 10 ft. by 6 ft.

The weedicides were dissolved (PCP) or suspended (CMU) in sufficient water to give a spraying rate of 100 gal. per acre over the soil surface. Before treatment, all weeds were removed by hand chipping. Sprays were applied by knapsack sprayer on July 27, following 0·12 in. of rain.

On Sept. 17 (52 days after treatment), weed counts, based on a 6 ft. by 1 ft. 6 in. random quadrat, were made in each plot. Grasses and other weed species were counted and recorded separately. The data are summarised in Table 1.

Table 1.

Weed Counts Per Square Yard 52 Days after Treatment.

Treatment.	Grasses.	Other Weeds.
(A) PCP 10 lb./ac.	25·7	18·4
(B) CMU 2 lb./ac.	21·8	6·7
(C) CMU 4 lb./ac.	9·1	3·6
(D) Control	32·3	63·0
	C<D, A, B. B<D	C, B, A<D

The main species present were:—

(*a*) *Grasses*: *Rhynchelytrum repens* (red Natal grass), *Digitaria adscendens* (summer grass) and *Eleusine indica* (crowsfoot grass).

(*b*) *Other Weeds*: *Ageratum houstonianum* (billygoat weed), *Stachys arvensis* (stagger weed) and *Stylosanthes sundaica* (Townsville lucerne).

Most of the weeds appearing in treated plots were in close proximity to the pineapple plants, suggesting faulty coverage by the sprays.

The trial was under observation for several months after the weed counts were made, and no toxicity symptoms were recognisable in any of the pineapple plants.

III. 1954–55 TRIAL.

The second trial followed closely on the first, and was commenced in November 1954 in an area of pineapples planted in the previous March. The same materials were used, but treatments included higher rates of CMU and PCP, and were:—

(A) PCP 10 lb. per acre.
(B) PCP 20 lb. per acre.
(C) CMU 4 lb. per acre.
(D) CMU 8 lb. per acre.
(E) Control—untreated.

The trial was laid out as 8 x 5 randomised blocks of plots 10 ft. by 6 ft., as in the previous year.

Sprays were prepared as in the first trial. The spraying rate was increased from 100 gal. to 300 gal. per acre, to improve the coverage, which appeared to have been inadequate in the first trial. Sprays were applied on Nov. 23, 1954.

Weed counts were on the same basis as those of the previous trial, and were made on Jan. 12 and Feb. 2, 1955 (50 and 71 days respectively after treatment). The results appear in Table 2.

Table 2.

WEED COUNTS PER SQUARE YARD 50 AND 71 DAYS AFTER TREATMENT.

Treatment.	50 Days.		71 Days.	
	Grasses.	Other Weeds.	Grasses.	Other Weeds.
(A) PCP 10 lb./ac.	52·8	16·1	86·3	65·7
(B) PCP 20 lb./ac.	24·2	6·1	59·6	57·3
(C) CMU 4 lb./ac.	15·9	3·9	35·3	17·6
(D) CMU 8 lb./ac.	11·8	3·5	20·0	9·6
(E) Control	69·4	25·2	112·8	106·5
	D, C<<E, A B<<E D<B B<A	D, C<<E, A B<<E B<A	D<<E, A, B C<<E C<A	D<<E, A, B C<<E C<A, B

The same weed species were encountered as in the previous trial, but populations were generally higher. Fewer weeds survived close to the plants than in the first trial, presumably due to the better coverage afforded by the higher spraying rate.

Even at 8 lb. per acre CMU failed to produce any injury to the pineapple plants in treated plots.

IV. 1956 FIELD TRIALS.

Since the two trials at Maroochy Experiment Station had demonstrated that CMU was an effective and safe weedicide for use in pineapples, further trials were undertaken to obtain additional information on rates of application. These were carried out during 1956 as follows:—

(1) On a brown sandy loam at Woombye (Apr. 27, 1956.)

(2) On a reddish-brown sand at Curra, near Gympie (May 2, 1956.)

(3) On a red clay loam at Buderim (June 22, 1956.)

In these trials a commercial product ("Karmex W"), containing 50 per cent. CMU as a dispersible powder, was used. The treatments in all three trials were:—

(A) PCP 10 lb. per acre.

(B) CMU 2 lb. per acre.

(C) CMU 4 lb. per acre.

(D) CMU 6 lb. per acre.

(E) Control—untreated.

They were laid out 6 x 5 randomised blocks of plots 20 ft. by 6 ft.

The spraying rate was reduced to 200 gal. per acre, a rate intermediate between the two rates used previously.

Weed counts were made as before on the basis of 1 sq. yd. random quadrats, and the results are given in Tables 3 and 4. For the purposes of statistical analyses the log (1 + x) transformation was used, and the figures shown in the tables are the "equivalent numbers" calculated from the transformed data.

Table 3.

"Equivalent Number" of Grasses per Square Yard.

Treatment.	Woombye Apr. 27–Aug. 29 (123 Days).	Curra May 2–Sept. 7 (128 Days).	Buderim June 22–Aug. 29 (68 Days).
(A) PCP 10 lb./ac.	5	19	11
(B) CMU 2 lb./ac.	12	5	1
(C) CMU 4 lb./ac.	4	3	0
(D) CMU 6 lb./ac.	2	2	1
(E) Control	26	21	18
	D<<E, B C<<E	B, C, D<<E, A	B, C, D<<E, A

Table 4.

"Equivalent Number" of Other Weeds per Square Yard.

Treatment.	Woombye Apr. 27–Aug. 29 (123 Days).	Curra May 2–Sept. 7 (128 Days).	Buderim June 22–Aug. 29 (68 Days).
(A) PCP 10 lb./ac.	5	34	31
(B) CMU 2 lb./ac.	10	2	122
(C) CMU 4 lb./ac.	1	1	28
(D) CMU 6 lb./ac.	1	0	12
(E) Control	61	199	174
	C, D<<E, B A, B<<E	B, C, D<<A	D, C, A<<E, B

Much the same weed species were involved as in the Maroochy Experiment Station trials, except at Buderim, where the principal species were *Fumaria officinalis* (common fumitory) and *Eleusine indica*. Fumitory was the dominant weed; it germinated freely and appeared to be rather resistant to CMU and, to a lesser extent, to PCP.

V. DISCUSSION.

The results of these trials clearly show that effective control of all the species of weeds encountered may be obtained with CMU at 4 lb. per acre. No significant decrease in weed survival was achieved by increasing the rate of application to either 6 lb. or 8 lb. per acre. In three of the five trials, 4 lb. per acre was significantly better than 2 lb. per acre.

At 4 lb. per acre CMU gave better control of weeds than PCP, even where the dosage of the latter was increased to 20 lb. per acre, and it has the added virtue of being innocuous to handle. Because of its relative insolubility, however, it requires constant and thorough agitation during spraying.

VI. ACKNOWLEDGEMENTS.

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MOLASSES AND UREA AS A SUPPLEMENT TO LOW QUALITY PASTURE HAY FOR CATTLE

By R. M. BEAMES, B.Agr.Sc., Animal Research Institute, Yeerongpilly.

SUMMARY.

Three groups of four Hereford heifers were fed individually in stalls for 16 weeks on rations of low quality hay, hay plus molasses, and hay plus molasses and urea. Hay was fed ad lib., molasses at 1.5 lb. per day and urea at 3.6 oz. per day. The hay was low in crude protein (3.5 per cent.) and high in crude fibre (38.5 per cent.).

Body weight losses in the group receiving molasses and urea were negligible. The average daily body weight losses in the groups receiving hay alone and hay plus molasses were 1.20 and 0.85 lb. respectively. There was no significant difference between these two rates but both were significantly greater than that in the group receiving molasses and urea ($P<0.01$). This last group made slower weight gains on pasture after the conclusion of the experiment.

Molasses had little effect on hay intake, whereas molasses plus urea increased hay intake by 38.8 per cent. ($P<0.01$).

Both molasses and molasses plus urea tended to increase the apparent digestibility of the hay. Apparent urea nitrogen digestion was 85–90 per cent.

I. INTRODUCTION.

During the winter and spring months in many areas of Queensland, the only feed available for grazing cattle is mature grass, the low nutritive value of which is often further reduced by frosts. This type of feed is low in protein, net energy and phosphate. In some areas either a phosphate lick or molasses is fed as the sole supplement. Such supplements would seem to be of limited value where animals are grazing standing hay which has a protein content insufficient to replace even the metabolic faecal nitrogen loss. Harvey (1952) showed that in some Queensland grasses fed to sheep—e.g. *Chloris gayana* (Rhodes grass) and *Astrebla* spp. (Mitchell grasses)—protein digestibility decreases with crude protein content until, in grass of approximately 4 per cent. crude protein, the apparent protein digestibility is zero. Thus, it would appear that before a marked response can be obtained from energy or phosphate supplements, nitrogen must be provided.

Nitrogenous supplements can be provided in the form of roughages (legume hays), concentrates (meatmeal and oilseed meals), and non-protein nitrogen (N.P.N.) In Queensland, roughages are generally an expensive source of protein, especially in winter and spring. In descending order of cost come oilseed meals and meatmeal, with N.P.N. as the cheapest source of nitrogen.

Much work has been done on the feeding and utilisation of N.P.N. but there has been comparatively little done on its use as the sole source of nitrogen in a supplement for ruminants on poor quality pasture. This aspect was studied in South Africa by Clark and Quin (1951) with sheep and by Clark and Barrie (1954) with cattle. In the experiment of Clark and Quin, various sources of N.P.N. were investigated and the two most promising were urea and sodium nitrate. As urea is the cheaper source of nitrogen in Queensland, it was considered more suitable for use in the present investigation. Molasses was used as the source of carbohydrate, being cheaper on a starch equivalent basis than grains.

An experiment was undertaken to determine whether carbohydrate supplementation alone is effective in reducing weight losses of cattle on low quality roughage or whether the addition of nitrogen is also necessary. No attempt was made to investigate the addition of nitrogen without carbohydrates.

Three groups of four heifers were fed hay alone, hay plus molasses, and hay plus molasses and urea respectively for a period of 16 weeks. Body weight changes and feed intakes were recorded and apparent digestibilities were determined.

II. MATERIALS AND METHODS.

(1) Animals.

The experimental animals were maiden Hereford heifers $2\frac{1}{2}$–3 years old in forward store condition, bred and reared in southern Queensland on predominantly paspalum (*Paspalum dilatatum*) pastures.

(2) Housing.

The animals were kept under cover in individual stalls with concrete flooring and troughing. The stalls were separated by a tubular steel framework, and the troughing, which was continuous, had $\frac{1}{4}$ in. steel-plate dividers. Softwood shavings were supplied as bedding except during the digestibility trial, when the floors were left bare. Consumption of bedding was negligible.

(3) Ration Components.

Pasture Hay.—The hay was obtained from the Central Highlands of Queensland. The major species present were *Dichanthium sericeum* (Queensland blue grass), *Eriochloa* sp. near *pseudoacrotricha, Thellungia advena* (coolibah grass), *Panicum decompositum* (native millet), *Paspalidium globoideum* (shot grass), *Aristida leptopoda* (white spear grass), and *Iseilema membranaceum* (small Flinders grass).

Molasses.—Cane molasses was obtained from the Moreton Sugar Mill, Nambour, Queensland.

*Urea**.—The urea was chemically pure and contained 46·5 per cent. nitrogen.

Salt-Phosphate Supplement.—This was a 50/50 coarse salt-bonemeal mixture. The bonemeal was degelatinised (phosphorus 12·2 per cent., calcium 31·2 per cent., crude protein 10·2 per cent.). Cobalt chloride was incorporated to supply 17 mg. cobalt per head per day.

(4) Analytical Methods and Techniques.

Feed and faeces were analysed by the official A.O.A.C. methods (Association of Official Agricultural Chemists 1955), molasses as in Laboratory Manual for Sugar Mills (Bureau of Sugar Experiment Stations, Queensland 1954), and plasma vitamin A and carotenoids by the method of Pierce (1945).

In the digestibility trial, faeces were collected by harness based on the design of Ballinger and Dunlop (1946), the only major modification being that the urine conduit was replaced by a rubber apron on a wire frame fastened to the animal by rubber strips and black "Bostick"† cement. This cement was not entirely satisfactory as it is irritant and also loses its adhesive properties rapidly when used as described.

III. EXPERIMENTAL.

Fifteen heifers in fat condition were stalled seven weeks prior to the commencement of the experiment and were fed a sub-maintenance ration of 8 lb. medium quality lucerne chaff per head per day to reduce body weight (from average 834 lb. to average 778 lb.). During the last two weeks of this pre-experimental period all animals were also given limited amounts of hay, molasses and urea to accustom them to these feedstuffs. From these 15 heifers, 12 were chosen on the basis of weight and behaviour, allotted by stratified random sampling with respect to body weight into three groups of four, and individually fed the following rations:—

Group I: Hay *ad lib.*

Group II: Hay *ad lib.* + 1·5 lb. molasses per head per day.

Group III: Hay *ad lib.* + 1·5 lb. molasses + 3·6 oz. urea per head per day.

All animals were fed daily 2 oz. of the salt-bonemeal supplement in separate containers.

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*"Ureafol". Kindly donated by Imperial Chemical Industries of Australia and New Zealand Ltd.

†B.B. Chemical Company of Australia Pty. Ltd., Abbotsford, N.9, Vic.

The molasses and the molasses-urea mixture were fed twice daily in tins separately from the hay. These supplements were prepared weekly by mixing with water (molasses 2 : water 1; and molasses 2 : water 1 : urea 0·3 respectively). Over this period of one week the mixture showed no deterioration.

Hay was fed out twice daily and was before the animals at all times. To facilitate ease of weighing and handling and to minimise wastage, the hay was chaffed in a cutter set to half-an-inch. Hay residues, which were collected daily before the morning feed, were weighed, sampled for chemical analysis and discarded. Proportionate samples of the hay as fed were collected daily.

There were no residues from the molasses and molasses-urea mixtures.

Plasma vitamin A was determined for two animals from each group at the conclusion of the experiment.

Body weight was recorded fortnightly at 9 a.m. on scales accurate to 2 lb. There was no period of starvation or water restriction before weighing.

Towards the conclusion of the experiment, a digestibility trial was done on two animals from each group. Over the pre-collection and collection periods, feed presentations were slightly below the estimated respective unrestricted intakes. No data on nitrogen balance were obtained.

The duration of the experiment was 16 weeks. The cattle were then put onto a predominantly paspalum pasture, which for the first month was in short supply because of dry weather but thereafter provided good grazing. Body weight was recorded for the first 15 weeks on pasture.

IV. RESULTS.

(1) Analyses.

Analyses of the hay as fed, hay residues and molasses are given in Tables 1a and 1b.

Table 1a

ANALYSES OF HAY AND HAY RESIDUES.

—	Percentage of Hay Presented.	Percentage Composition.						
		Moisture.	Dry-matter Basis.					
			Protein.	Ether Extract.	Fibre.	N.F.E.	Ash.	Ca.	P.
Hay as fed ..		4·9	3·5	1·0	38·6	47·0	9·9	0·43	0·12
Hay Residues—									
Group I. ..	17·0	5·3	3·8*	1·0	35·8*	47·5	11·9*	†	†
Group II. ..	18·4	5·3	4·1*	1·0	35·2*	48·4	11·3*	†	†
Group III. ..	12·8	5·3	3·9*	1·0	36·3*	47·3	11·6*	†	†

* Significantly different ($P < 0.01$) from hay as fed.
† Not analysed.

Table 1b

ANALYSIS OF MOLASSES.

	Per cent.		Per cent.
Moisture	25·5	Potassium (K)	1·99
Sucrose	34·6	Nitrogen (N)	0·8
Reducing Sugars	9·4	Phosphorus (P)	0·05
Ash	14·6	Calcium (Ca)	0·81

The residues were significantly higher in protein and ash and lower in fibre than the hay fed. These residues were dusty and probably contained a higher proportion of leaf, seed and soil. Average daily air-dry residues for Groups I, II and III were 2·10, 2·20 and 2·10 lb. respectively.

(2) Body Weight.

Initial and final body weights are given in Table 2, and fortnightly changes are shown in Fig. 1.

Table 2

BODY WEIGHT CHANGES AND HAY CONSUMPTION OVER 16 WEEKS' EXPERIMENTAL PERIOD.

Group.	Mean Body Weight (lb.).				Net Mean Daily Air-Dry Hay Consumption (lb.).
	Initial.	Final.	Change Per Day.	After 15 Weeks on Pasture.	
I.	785	650	−1·20	851	10·26
II.	762	667	−0·85	847	9·78
III.	787	778	−0·09	910	14·24
Between I. and II.			N.S.		N.S.
Between I. and III.			*		*
Between II. and III.			*		*

N.S. Not significant.
* ($P<0·01$).

The animals receiving hay without supplement (Group I) showed a steady decline in liveweight, with an average loss of 1·20 lb. per day. Those receiving a supplement of molasses (Group II) lost weight at an average of 0·85 lb. per day. However, the difference between Group I and Group II was not significant and for most of the experimental period rate of body weight loss in these two groups was similar (Fig. 1). Those animals supplemented with molasses and urea (Group III) had a mean weight loss of 0·09 lb. per day. This weight loss in Group III was significantly less ($P<0·01$) than in Group I and Group II.

Post-experimental weight gains on pasture were greater in Groups I and II than in Group III. The first two groups made average body weight gains of 201 and 180 lb. respectively over the first 15 weeks, while Group III gained only 132 lb. in the same time.

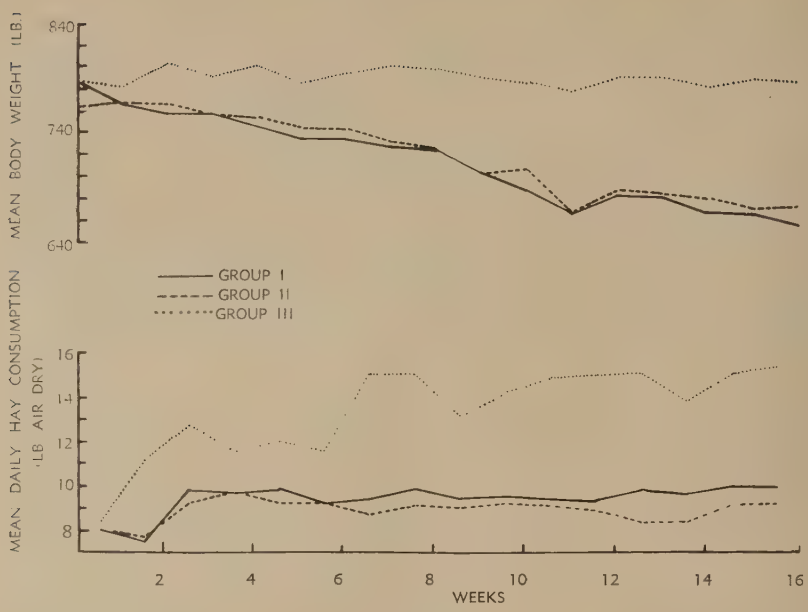

Fig. 1.

Body Weight Changes and Hay Intakes of Heifers in Group I (Hay Only), Group II (Hay and Molasses) and Group III (Hay, Molasses and Urea).

(3) Feed Intake.

The average daily hay consumptions are given in Table 2, and progressive changes are shown in Fig. 1.

In Group II the feeding of molasses decreased hay intake by approximately 0·5 lb. per head per day (Table 1). This decrease was not significant. When urea was incorporated in the supplement (Group III), the hay intake was significantly increased by 38·8 per cent. ($P<0·01$).

(4) Digestibility Trial.

The results of the digestibility trial on the two animals from each group are presented in Table 3. These data were not statistically analysed because of the small number of cattle used.

Average dry matter digestibility was increased in the supplemented rations (from 32·5 per cent. in Group I to 44·9 per cent. and 43·0 per cent. in Groups II and III respectively). Addition of molasses increased the average apparent protein digestibility, which was 10·1 per cent. for Group II, compared

Table 3

RESULTS OF DIGESTIBILITY TRIAL.

Animal No.	Average Dry Matter Intake Per Day (lb.).	Digestibility Coefficients.			
		Dry Matter.	Protein.	N.F.E.	Fibre.
Group I.					
Number 32	8·6	30·6	4·5	28·2	44·2
Number 34	11·6	34·4	0·9	34·6	43·6
Average	10·1	32·5	2·7	31·4	43·9
Group II.					
Number 4	9·8	44·7 (25)†	9·2	46·6 (2)†	56·6 (28)†
Number 6	13·0	45·2 (8)†	11·1	44·0 (16)†	47·4 (8)†
Average	11·4	44·9	10·1	45·3	52·0
Group III.					
Number 8	15·8	41·4 (10)†	51·4 (86)*	42·4 (14)†	52·5 (16)†
Number 10	16·3	44·6 (20)†	53·6 (91)*	43·7 (16)†	54·1 (22)†
Average	16·0	43·0	52·5	43·0	53·3

* Apparent urea-N digestibility percentages.
† Apparent increases in digestibility coefficients of respective components in the hay.

with 2·7 per cent. for Group I. Apparent urea nitrogen digestibility was 85–90 per cent. The average apparent fibre digestibility was increased from 43·9 per cent. to 52·0 per cent. by the addition of molasses and to 53·3 per cent. by the addition of molasses and urea.

(5) Vitamin A.

Plasma vitamin A levels for two animals from each group were within the range 20–31 μg. per 100 ml. at the end of the experimental period. These levels were within the normal range.

V. DISCUSSION.

In this experiment, maiden heifers in forward store condition, fed low quality pasture hay *ad lib.* and supplemented with 1·5 lb. molasses and 3·6 oz. urea per head per day, maintained body weight for 16 weeks. Similar animals without supplement, or supplemented with molasses only, lost considerable weight.

There are at least three applications of these findings. The first is the use of conserved pasture hay, supplemented or sprayed with molasses and urea, as a maintenance fodder for cattle. The second is the spraying of a molasses-urea mixture on low quality pasture, provided the density of the plant cover is adequate and the sprayed material can be consumed within a few days. This procedure has been described by Kellermann and Groenewald (1956). A third application, which so far has not been extensively investigated, is the provision of a molasses-urea mixture in troughs, either *ad lib.* or under controlled conditions. Mechanical means or additives would be necessary to reduce rate of intake and so avoid toxicity. Additives would make the mixture similar in nature to a protein meal-salt supplement of the type used extensively in America (Riggs, Colby and Sells 1953). Feeding from troughs under controlled conditions has been practised (Kellermann and Groenewald 1956), while *ad lib.* feeding in U.S.A. has been mentioned by Hale (1954).

Molasses was fed with the urea to increase palatability and provide cheap, readily available carbohydrate. This provision of readily available carbohydrate conforms with most recommendations on urea feeding and is supported by the *in vivo* studies of Mills *et al.* (1942), who showed that urea is not utilised efficiently when superimposed on a ration of hay alone. They demonstrated that the presence of starch allows for a more rapid conversion of ammonia nitrogen to bacterial protein. However, Arias *et al.* (1951), measuring urea utilisation by the breakdown of urea to ammonia in the artificial rumen, found that corncobs were as effective a source of energy as molasses, dextrose, sucrose or starch. As urea utilisation should be measured by the increase in bacterial protein, these results do not necessarily conflict with those of Mills *et al.* (1942).

Digestibility data (Table 1) show that molasses tends to increase fibre digestion in the hay, but this difference was not reflected in the weight changes. This is similar to results obtained by Hoflund, Quin and Clark (1948), who showed that sucrose levels of less than 9 per cent. improved cellulose digestion in sheep but gave no improvement in body weight. Briggs and Hiller (1943, 1945) could not demonstrate this effect and in some cases even observed a reduction in fibre digestibility of sheep fed various levels of molasses. This lack of effect conforms with the reasoning of Crampton and Maynard (1938), who maintained that lignin content of hay controls digestibility of cellulose. Clark and Quin (1951) also were unable to show improvement in cellulose digestibility by the addition of a 12 per cent. molasses–4 per cent. urea supplement to a sheep ration of veld hay (4·7 per cent. crude protein) and maintained that percentage digestibility of cellulose is not sufficient as an index of utilisation, where rate of digestion also must be considered. In general, opinion tends to be against any substantial beneficial effect of carbohydrate supplementation on fibre digestibility.

In this experiment the addition of molasses and molasses-urea increased the average digestibility of fibre by 18·5 and 21·5 per cent. respectively. As this increase in fibre digestibility in the group receiving molasses did not improve hay intake, it would not be justifiable to assume that the increased fibre digestibility in the group receiving molasses-urea was contributing to the 38·8 per cent. increase in hay intake. Nor can the increased intake in this latter group be attributed to palatability, as the supplements were fed separately from the hay. The differences in intake, therefore, must be correlated to a large extent with rate of digestion.

The apparent digestibility of urea nitrogen in Group III was 90 per cent. This is similar to figures obtained by Nehring and Schramm (1939), who found that by adding urea to a sheep ration the apparent digestibility of urea nitrogen was 95 per cent.

The effect of supplementing poor quality hay with molasses and molasses-urea on liver copper levels was studied concurrently with this experiment and is described by Beames (1959).

VI. ACKNOWLEDGEMENTS.

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A NOTE ON THE EFFECT OF MOLASSES ON LIVER COPPER CONCENTRATIONS IN CATTLE

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SUMMARY.

Three groups of four Hereford heifers were fed individually in stalls for 16 weeks on rations of low quality hay, hay plus molasses, and hay plus molasses and urea. It was found that the last two treatments significantly depleted liver copper concentrations over this period, while the first treatment had no effect in this regard.

I. INTRODUCTION.

The observations in this paper were made in conjunction with an experiment reported by Beames (1959) which was designed to evaluate molasses and urea as a supplement to poor quality hay. In that experiment, three groups of four maiden Hereford heifers were chosen by random selection and individually fed in stalls on the following rations:—

Group 1: Hay *ad lib.*

Group II: Hay *ad lib.* + 1·5 lb. molasses per head per day.

Group III: Hay *ad lib.* + 1·5 lb. molasses + 3·6 oz. urea per head per day.

In addition, all animals received 2 oz. per day of a 50/50 coarse salt-bonemeal mixture. The bonemeal was degelatinised (phosphorus 12·2 per cent., calcium 31·2 per cent., crude protein 10·2 per cent. in the bonemeal). Cobalt chloride was incorporated to supply 17 mg. cobalt per head per day.

The experimental animals were taken from pastures which were known to give low liver copper concentrations in cattle. Copper treatments were given therefore to each animal at the commencement of the experiment. Liver biopsy samples were taken for analysis for copper at the 2nd and 16th weeks of the experiment.

II. METHODS AND MATERIALS.

The feed was analysed by the methods of the Association of Official Agricultural Chemists (1955); molasses as in Laboratory Manual for Sugar Mills (Bureau of Sugar Experiment Stations, Queensland 1954); copper in liver and feed as in Clare, Cunningham and Perrin (1945); and molybdenum and sulphate in feed by the methods of Dick and Bingley (1951), and Bingley and Dick (private communication, 1953) respectively.

Liver samples were obtained by biopsy with the instruments described by Dick (1944) and using the technique of Loosmore and Allcroft (1951). Copper treatments were given intravenously by flutter valve, using 0·5 per cent. copper sulphate ($CuSO_4.5H_2O$) in distilled water.

III. EXPERIMENTAL.

Each animal was given two injections of 50 ml. 0·5 per cent. copper sulphate solution, the first at the commencement of the experiment, the second one week later. Liver samples were taken one week after the second injection and again 14 weeks later, at the conclusion of the experiment.

Representative samples of hay, bonemeal, salt and molasses were analysed.

IV. RESULTS.

Proximate analysis of feeds are given in Tables 1a and 1b. Copper, molybdenum and inorganic sulphate content of all feedstuffs and the average intake of each group are shown in Table 2.

Table 1a.

PROXIMATE ANALYSIS OF BUSH HAY.

	Percentage Composition (Air-dry Basis).							
	Moisture.	Protein.	Ether Extract.	Fibre.	N.F.E.	Ash.	Calcium (Ca).	Phosphorus (P).
Hay as fed	4·9	3·3	1·0	36·6	44·7	9·5	0·41	0·11

Table 1b.

ANALYSIS OF MOLASSES.

	Per cent.		Per cent.
Moisture	.. 25·5	Potassium (K)	.. 1·99
Sucrose	.. 34·6	Nitrogen (N)	.. 0·8
Reducing Sugars	.. 9·4	Phosphorus (P)	.. 0·05
Ash	.. 14·6	Calcium (Ca)	.. 0·81

Molasses with 17 p.p.m. copper raised the copper intake in Groups II and III. Sulphate intake was increased considerably in Groups II and III because of the high sulphate content (2·33 per cent.) of the molasses. Molybdenum content of the ration was not substantially altered by the addition of molasses. The urea was chemically pure and consequently did not contribute to the copper, molybdenum or inorganic sulphate content of the ration.

Table 2.

COPPER, MOLYBDENUM AND INORGANIC SULPHATE CONCENTRATIONS OF AIR-DRY FEEDSTUFFS AND AVERAGE INTAKES OF GROUPS I., II. AND III.

Copper, Molybdenum and Inorganic Sulphate Concentration.

——	Copper. (p.p.m.).	Molybdenum. (p.p.m.).	Inorganic Sulphate. (%).
Hay	4·4	0·56	0·065
Molasses	17.0	0·21	2·33
Urea	Chemically pure		
Salt	0·6	0·15	0·34
Bonemeal	1·8	0·25	0·59

Mean Proportions in Ration and Mean Daily Intake.

Group.	Total Intake (lb. Air-dry).	Copper.		Molybdenum.		Inorganic Sulphate.	
		(p.p.m.).	(mg.).	(p.p.m.).	(mg.).	(%).	(g.).
I. ..	10·38	4·37	20·6	0·555	2·6	0·07	3·3
II. ..	11·40	6·02	31·3	0·505	2·6	0·37	19·0
III. ..	16·08	5·49	40·58	0·517	3·8	0·27	20·2

Liver copper levels are given in Table 3. There was no significant difference in liver copper level between groups one week after the final injection. Over the experimental period the rise in liver copper concentration in Group I from mean 148 p.p.m. to mean 153 p.p.m. was not significant. The mean falls from 157 p.p.m. to 78 p.p.m. in Group II and 139 p.p.m. to 50 p.p.m. in Group III were significant ($P<0·01$). At the conclusion, liver copper level in Group I was significantly greater ($P<0·01$) than those in Groups II and III.

Table 3.

LIVER COPPER CONCENTRATIONS.

Group.	Liver Copper (p.p.m.) on Dry-matter Basis.	
	One Week after Injections.	Completion of Experiment.
I.	148	153
II.	157	78
III.	139	50
Difference between I. and II.	N.S.	*
Difference between I. and III.	N.S.	*
Difference between II. and III.	N.S.	N.S.

* $P>0·01$.
N.S. Not significant.

V. DISCUSSION.

The results show that the supplementing of hay with molasses, either alone or in combination with urea, caused significant reduction in liver copper concentration. This was despite the fact that copper intake was greater in the two groups receiving molasses than in the control group.

These results indicated that some factor or combination of factors in molasses limits copper storage, and led to an examination of the molybdenum and inorganic sulphate levels in the ration components.

The level of molybdenum in these rations (approximately 0·5 p.p.m.) is lower than limiting levels discussed by either Marston (1950) or Wallace (1950), though Dick (1953) stated that an intake of molybdenum of 0·3–0·5 mg. per day for sheep (0·3–0·5 p.p.m. on an intake of 1 kg.) is sufficient to limit copper storage in the presence of sufficient inorganic sulphate. According to Dick, the level of sulphate (0·37 and 0·27 per cent.) in the ration for Groups II and III respectively would be considered sufficient to permit molybdenum to limit copper storage in sheep, while the 0·07 per cent. inorganic sulphate in the ration of Group I would be insufficient. Making the assumption that the above data in sheep would apply to cattle, the reduction in liver copper reserves in Groups II and III could be explained on the basis of a copper-molybdenum-inorganic sulphate interaction.

The findings of Allcroft and Lewis (1956) tend to contradict this hypothesis. These workers recorded levels of copper, molybdenum and inorganic sulphate, similar to those in Table 2, in pastures which did not produce copper deficiency in cattle, and postulated that further potent factors affecting copper metabolism remained to be discovered. Such factors may be present in molasses.

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TECHNICAL NOTES

TOXICITIES OF INSECTICIDES TO PASTURE WHITE GRUBS IN QUEENSLAND

E.M.N.

During 1947, R. C. Cannon (unpublished Departmental records) established large-scale field trials using heavy dressings of BHC to combat white grubs in pastures on the Atherton Tableland. The results indicated that another approach was necessary and as part of further investigations insecticide screenings against larvae in pots were undertaken during 1954 and 1955.

Larvae of *Rhopaea magnicornis* Blkb. and *Lepidiota caudata* Blkb. (see Saunders 1958) were bred (first-stage R. *magnicornis*) (Fig. 1) or collected in the field (second and third stages) and first-stage *Dermolepida albohirtum*

Fig. 1.

Breeding Cages Used for Obtaining Supplies of First-stage Larvae.

Waterh. (bred) were used in one series as this species is controlled in sugar-cane fields by applications of BHC (Mungomery 1949, Wilson 1956).

The insecticides were thoroughly mixed with air-dry soil from relevant habitats, but p.p.m. (active) were calculated on oven-dry weights. Either one third-stage, two second-stage, or five first-stage larvae were placed in each pot containing about 1 lb. of soil (and insecticide) kept suitably moist. No fewer than 100 larvae per treatment were used. When examining larvae the pot contents were placed in a scoop, and after adding water, if required, were returned to the pot.

The materials used were:—

BHC.—A 20 per cent. kaolin dust containing 2·6 per cent. gamma isomer.

Aldrin.—A graulated preparation, 2·5 per cent. active.

DDT.—A kaolin dust containing 10 per cent. *p.p'* isomer.

Where necessary these were diluted with kaolin before mixing with soil. Kaolin in controls did not influence larval mortalities.

Results are presented under the Melolonthid species concerned. Those for the series with first stages are summarised only.

RESULTS.

Rhopaea magnicornis.

First-stage Larvae.—A series was set up at Brisbane on Feb. 12, 1955. Treatments were: BHC, 1, 2 and 3 p.p.m.; aldrin, 1, 2, and 3 p.p.m.; DDT 20,

Table 1.

Toxicity of Insecticides to Second-Stage Larvae of *Rhopaea magnicornis.*

Treatment.	Percentage Mortality.		
	At 14 Days.	At 28 Days.	At 63 Days.
BHC 10 p.p.m.	28·6	64·3	64·3
BHC 20 p.p.m.	33·2	50·0	50·0
BHC 30 p.p.m.	16·6	64·3	64·3
Control	14·3	57·1	57·1
Aldrin 10 p.p.m.	30·9	52·4	69·0
Aldrin 20 p.p.m.	23·8	40·5	50·0
Aldrin 30 p.p.m.	11·9	24·3	69·0
Control	26·2	38·1	71·4
DDT 200 p.p.m.	35·9	42·9	92·8
DDT 400 p.p.m.	42·9	54·7	85·7
DDT 600 p.p.m.	35·9	52·4	90·5
Control	21·4	45·2	60·5

40 and 60 p.p.m. On examination at 28 days mortality in the controls was 63·3 per cent. The treatments showed an equal or better survival, indicating that there were no effects due to insecticides.

Second-stage Larvae.—A series was set up at Brisbane on Feb. 12, 1955. Details of treatments and results are given in Table 1.

Third-stage Larvae.—A series using 1,200 larvae was set up at Brisbane on Jan. 29, 1954. Details of treatments and results are given in Table 2.

Table 2.

Toxicity of Insecticides to Third-Stage Larvae of *Rhopaea magnicornis.*

Treatment.	Percentage Mortality.	
	At 14 Days.	At 28 Days.
BHC 0·5 p.p.m.	2·0	6·5
BHC 1·0 p.p.m.	9·0	9·0
BHC 1·5 p.p.m.	8·0	14·5
BHC 2·0 p.p.m.	3·0	8·0
BHC 2·5 p.p.m.	2·0	7·0
Control	2·0	11·5

Lepidiota caudata.

Third-stage Larvae.—A series was set up at Ayr on Mar. 16, 1955. Details of treatments and results are given in Table 3.

Table 3.

Toxicity of Insecticides to Third-Stage Larvae of *Lepidiota caudata.*

Treatment.	Percentage Mortality at 28 Days.
BHC 5·0 p.p.m.	72·1
BHC 10·0 p.p.m.	75·0
BHC 15·0 p.p.m.	100·0
BHC 20·0 p.p.m.	81·5
BHC 50·0 p.p.m.	87·0
Aldrin 0·5 p.p.m.	5·0
Aldrin 1·0 p.p.m.	6·0
Aldrin 2·0 p.p.m.	9·0
Aldrin 4·0 p.p.m.	10·0
Aldrin 6·0 p.p.m.	5·0
DDT 40·0 p.p.m.	24·0
DDT 120·0 p.p.m.	36·0
Control	11·0

Dermolepida albohirtum.

First-stage Larvae.—A series was set up at Ayr on Feb. 3, 1955. Treatments were BHC 0·5, 1·0, 2·0, 3·0 and 4·0 p.p.m.; aldrin 0·25, 0·5, 1·0, 2·0 and 4·0 p.p.m. On examination at 12 days mortality in the controls was 65·0 per cent. All insecticide treatments resulted in 100 per cent. kills.

DISCUSSION.

All larvae in BHC treatments came to the soil surface, indicating the deterrent effect of this soil insecticide.

As mortalities in the controls were often high, better methods for obtaining technically sound data are required. Placing the larvae in simulated tunnels did not improve results, and some exploratory work was undertaken with squares set in the ground (Fig. 2). This promising approach was not

Fig. 2.

Establishing Squares for White Grub Toxicity Studies.

persevered with, as results from the pot series indicated that BHC, aldrin and DDT are much more toxic to *D. albohirtum* than to *R. magnicornis* and *L. caudata*, and accordingly these materials would be of little value in the commercial control of pasture white grubs.

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BAG TREATMENT TO CONTROL PESTS OF HOODED SORGHUM

Head hooding with paper bags to prevent cross-pollination is an essential feature of sorghum breeding work. Conditions within these bags (Fig. 1) are ideal for the development of insects such as *Heliothis armigera* (Hubn.), *Cryptoblabes* sp. and *Aphis maidis* Fitch, and damage by these pests can be a limiting factor in the seed produced for plant-breeding purposes.

Fig. 1.
Hooded Sorghum Heads.

Control trials using paper bags fully or partially impregnated with an insecticide by thorough wetting and then drying were carried out at the Biloela Regional Experiment Station during 1955, 1956 and 1958. The bags, made of brown Kraft paper double crown 37, were prepared during the week prior to hooding. Immediately after harvesting, infestation ratings of 0–5 (severe) were recorded for species on each head in trials where pest numbers were high. For the later trials a similar rating range for fungi was used and samples for germination testing were taken.

1955 TRIAL.

A 5 x 4 randomised block layout was used with 20 heads per plot. The bags were fully immersed in the insecticide dips, and were placed on the heads on Apr. 6. Harvesting was on May 9. The results are given in Table 1.

Table 1.

RESULTS OF 1955 TRIAL.

Bag Impregnation Treatment.	Infestation (Mean Rating).	
	Cryptoblabes sp.	*A. maidis.*
DDT emulsion 1·0%	0·23	1·89
Aldrin emulsifiable preparation 0·5%	0	0
BHC dispersible powder 0·5% plus wetting agent	0	0
Check	2·10	0·85

Fungi (*Fusarium* spp. and *Rhinotrichum* sp.) were prevalent in all heads, particularly those in treated bags.

1956 AND 1958 TRIALS.

A 7 x 3 randomised block design was used with a plot size of 20 heads. As the 1955 trial was infested by fungi, half-impregnated bags were included as treatments. When the top half of a bag is impregnated, the treated portion is in contact with the lower parts of the sorghum head. Hooding and harvesting respectively were carried out on Mar. 20 and May 1, 1956, and on Apr. 15 and May 14, 1958. As the 1958 trial was only lightly infested by insect pests, mean numbers of pests per plot were recorded.

Sub-samples from all treatments were tested for germination. Insecticide treatments of bags and the presence of fungi did not influence germination: all tests were above 70 per cent. Other results are given in Table 2.

CONCLUSIONS.

These results, which are in general similar to those reported by Dahms, Sieglinger and Guthrie (1955), demonstrate that the use of bags dipped either completely or partially in 0·5 per cent. aldrin gives satisfactory control of *Heliothis armigera*, *Cryptoblabes* sp. and *Aphis maidis* infesting hooded sorghum heads. Completely impregnated BHC bags may be used as a substitute. DDT-treated bags do not control *A. maidis*.

Table 2.

RESULTS OF 1956 AND 1958 TRIALS.

Bag Impregnation Treatment.	1956 Trial.				1958 Trial.		
	Infestion (Mean Rating).				Infestation.		
					Mean Number Per Plot.		Mean Rating.
	H. armigera.	*Cryptoblabes* sp.	*A. maidis.*	Fungi.	*H. armigera.*	*Cryptoblabes* sp.	Fungi.
Complete bag. BHC dispersible powder 0·5% plus wetting agent	0·13	0	0	1·23	0·67	0	2·23
Top half of bag. BHC dispersible powder 0·5% plus wetting agent	0·63	0·03	0	1·33	1·00	0·33	1·92
Bottom half of bag. BHC dispersible powder 0·5% plus wetting agent	0·60	0	0·03	1·18	0	0	2·40
Complete bag. Aldrin emulsifiable preparation 0·5%	0·18	0·05	0·03	1·13	0	0·33	2·43
Top half of bag. Aldrin emulsifiable preparation 0·5%	0·20	0	0·07	1·40	0	0·33	1·87
Bottom half of bag. Aldrin emulsifiable preparation 0·5% ..	0·08	0·03	0·15	1·28	0·33	0	1·75
Check	0·57	0·23	1·20	1·25	4·33	9·00	1·80
Necessary difference for significance 5%	0·39						

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REMOVAL OF LEAD ARSENATE FROM GREEN TOBACCO LEAF

About 1950 the area of irrigated tobacco crops was expanded in Queensland, and consequently field planting in spring, rather than as previously after early summer rains, became general practice. As a result the pest status of the tobacco looper (*Plusia argentifera* Gn.) was increased considerably. This insect when in large numbers was not controlled satisfactorily by the insecticides used for other pests at that time, and lead arsenate, which had been used for many years for controlling leaf pests of tobacco, was applied intensively during the later stages of crop growth. During the 1951-52 season quantities of Queensland leaf were condemned because of excessive arsenic residues: the official tolerance is 1 grain As_2O_3 per lb. of moisture-free cured leaf.

The sound approach to the solving of residue problems is prevention, i.e. replacing the offending insecticide. This was done quickly and the use of arsenic is no longer necessary for controlling pests in Queensland tobacco fields (see Smith 1955). At the same time, however, some attention was given to the removal of lead arsenate from green leaf.

A dipping trial was carried out at Ayr during 1953. Following preliminary laboratory investigations the dip used contained 0·25 per cent. w/w HCl (5½ pt. commercial concentrate in 100 gal. water) and 0·25 per cent. detergent (22 per cent. secondary alkyl sulphate).

Leaf with arsenic residue was obtained from a crop planted on Sept. 12 and sprayed five times with lead arsenate (3 lb./50 gal.) and DDT (0·1 per cent.). The total spray used was at the rate of 426 gal. per acre, and the final application was made six days before harvesting on Jan. 7. During the growing period 4·6 in. of rain fell on seven wet days.

Twenty of the 24 sticks of leaf were successively dipped and agitated for 30 sec. in 60 gal. of the acid-detergent dip, drained for 30 sec., rinsed twice in 60 gal. of water, drained and then cured.

Analyses of cured leaf (approx. 1½ lb. per stick) are given in order of dipping in Table 1: sticks Nos. 21-24 comprised the control.

These analytical results indicate that arsenic residue can be removed from green leaf by dipping, but other factors would limit the commercial use of this method. For convenience, residues in Table 1 have been grouped, and the increase in average suggests that to keep residues below tolerance level either fairly frequent renewal of dipping fluids or topping up would be required.

Furthermore, although the quality of both treated and control leaf was variable and mostly poor, that of the former was distinctly papery.

Table 1.

RESULTS OF 1952–53 TRIAL.

Stick No.	As_2O_3 residue (grains/lb.).	
1 ..	1·12	
2 ..	1·12	Average 0·84
3 ..	0·70	
4 ..	0·42	
5 ..	0·42	
6 ..	0·84	Average 0·52
7 ..	0·56	
8 ..	0·28	
9 ..	0·56	
10 ..	1·12	Average 0·87
11 ..	0·42	
12 ..	1·40	
13 ..	0·98	
14 ..	1·96	Average 1·47
15 ..	1·54	
16 ..	1·40	
17 ..	1·40	
18 ..	0·98	Average 1·64
19 ..	2·66	
20 ..	1·54	
21 ..	18·48	
22 ..	22·40	
23 ..	9·24	
24 ..	13·30	

This trial was repeated at Inglewood during March 1955: the results were similar.

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A PRELIMINARY INVESTIGATION INTO CONTROL OF FALSE WIREWORM ON THE DARLING DOWNS

E. M. N.

Damage by the false wireworm, *Gonocephalum* sp. ? *macleayi*, Bla. (det. Commonwealth Institute of Entomology, Aug. 1958), to newly germinated crops, both summer and winter, occurs sporadically on the Darling Downs. When larval populations are high, extensive thinning of the stand occurs and replanting may be necessary. The areas most frequently affected are Clifton-Nobby, Evanslea-Mt. Irving, and to the west of Dalby.

Infestations usually occur on the lighter soil types and are noticeably worse on land where stubble of the previous crop has been ploughed in. A weedy fallow is ideal for false wireworm build-up. The beetles congregate around and under the weeds to oviposit, and this accounts for the subsequent scattered areas of larval attack.

On Nov. 11, 1957, a 4 x 4 latin square trial with a plot size of 1/100th acre was planted out in the Evanslea district to compare three strengths of BHC. The insecticide was diluted with rock phosphate, and the mixture applied as a drill dressing at the rate of 100 lb. per acre.

Stand counts were made in 12 random 3 ft. lengths of row per plot.

Details of treatments and results are given in Table 1.

Table 1.

TRIAL RESULTS—PLANT STANDS.

Treatment.	Nov. 22.		Jan. 16.	
	No. of Plants.	Mean Log.	No. of Plants.	Mean Log.
A 2 oz. g. i. BHC/acre	389	1·95	417	2·00
B 4 oz. g. i. BHC/acre	503	2·10	631	2·19
C 6 oz. g. i. BHC/acre	501	2·08	626	2·19
D Untreated (Rock phosphate 100/ac.) ..	215	1·69	233	1·56
Necessary differences for significance 5%		0·32		0·44
Necessary differences for significance 1%		0·49		0·66

Nov. 22, B, C > D
Jan. 16, A, B, C > D

The increased counts on Jan. 16 were due to further germination following rain.

All the strengths of BHC applied as a drill dressing gave a significant increase in stands, and thus a control of the false wireworm.

Damage by this pest is sporadic, and furthermore replantings are not always attacked. Preventive treatment therefore must be cheap and simple. Further work will be concerned with insecticide treatment of the grain before planting, an approach which has solved a similar problem—protection of cereal seed from attack by the seed-harvesting ant *Pheidole ampla* Forel.

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